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NOISE ABATEMENT OF VIBRATING SCREENS,

Using Non-Metallic Decks and Vibration Treatments

Prepared for

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

by

Allis-Chalmers Corporation
P.O. Box 512
Milwaukee, Wisconsin

FINAL REPORT

Contract No. HO387018

NOISE ABATEMENT OF VIBRATING SCREENS

January 1980

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16. Abstract (Limit: 200 words)

Noise from vibrating screens is generated in two ways: 1) Noise due to the material being processed and, 2) noise from the screen itself. Non-metallic decks had been shown previously to reduce material noise. The noise reduction and change in screening performance was quantified for six non-metallic decks using dolomite, granite and coal as the materials. The non-metallic decks were from 2 to 7 dBA quieter and from -1 to +10 percent less efficient as compared to a steel wire cloth deck of the same open area. Damping of the sidewalls and isolation of the drive mechanisms had been shown, in a development configuration, to reduce the noise of the screen itself. Tests of four prototype damping treatments gave reductions up to 4.9 dBA and the mechanism isolators gave an additional 2.1 dBA. The treatments were successfully life tested in two ways: 1) Lab tests to a simulated 25,000 hours were conducted on samples of the treatments in a corrosive salt spray to simulate coal plant wash water and, 2) the full size treatments were run on a full size screen for 5,000 hours.

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FOREWARD

This report was prepared by the Advanced Technology Center of Allis-Chalmers Corporation, P.O. Box 512, Milwaukee, Wisconsin, 53201, under USBM Contract number HO387018. The contract was initiated under the Metal and Nonmetal Health and Safety Research Program. It was administered under the technical direction of the Pittsburg Research Center with John G. Kovac acting as Technical Project Officer. Alan G. Bolton was the contract administrator for the Bureau of Mines. This report is a summary of the work recently completed as a part of this contract during the period July, 1978, to January, 1980. This report was submitted by the authors January, 1980.

A patent was filed by Allis-Chalmers Corporation for the mechanism isolators before the start of this contract. United States Patent number 4,180,458 was granted on December 25, 1979. No patentable features were designed during this contract.

EXECUTIVE SUMMARY

Introduction

One area of concern in reducing noise in the mining industry is the noise from vibrating screens. The noise from the screens can be divided into two parts, the noise caused by the material being screened and the noise from the screen itself.

One method of reducing material induced noise is the installation of non-metallic decks. Before the non-metallic deck can be recommended as a treatment of noise, its noise and efficiency performance should be measured.

Two methods of reducing the noise of the screen itself are isolation of the drive mechanisms and vibration damping of the sideplates. Allis-Chalmers developed these treatments under previous, corporate funded programs.

The objectives of this contract were to test six commercially available non-metallic decks for efficiency and noise, with three different materials, and to noise test and verify the life characteristics of production type installations of the drive mechanism isolators and sidewall damping.

Summary of Results

In addition to the six non-metallic decks, a steel wire cloth deck was tested for comparison. All decks had approximately 50 percent open area. Four tests were run with each of the seven decks, with three materials, coal, dolomite, and granite. The test results are summarized in Table 1. In general, a 2 to 7 dBA decrease in noise and a change in efficiency from +1 to -10 percent can be expected with a non-metallic deck as compared to a steel wire cloth deck. The loss in efficiency would be even greater if the non-metallic deck was compared to a standard wire cloth deck, which has more open area.

Three constrained layer damping treatments were carried through to testing, Antiphon, EAR and 3M. Reductions were from 3.7 to 4.9 dBA. Lab tests were conducted in a salt spray bath of samples of the damping treatments. The damping treatments should have a life of over 25,000 hours. Mechanical wear was not included in the tests. The mechanism isolators were then installed along with the Antiphon treated sideplates, which had given the largest reduction. The total reduction, of the two treatments, was 7.0 dBA. The combination was then life tested for 5,000 hours, with no loss in performance.

TABLE 1. - Summary of deck test results, by comparison to steel wire cloth performance

Deck	Material					
	Dolomite (at 525 tons per hour)		Granite (at 525 tons per hour)		Coal (at 400 tons per hour)	
	Relative efficiency, percent	Relative sound pressure level, dBA	Relative efficiency, percent	Relative sound pressure level, dBA	Relative efficiency, percent	Relative sound pressure level, dBA
Gates, steel back	-1	-7	-1	-6	+4[1]	-4[1]
Goodrich, composite	-2	-5	-4	-6	-8	-6
Linatex, steel back	+1	-4	-2	-2	-2	-2
Trelleborg	-5	-4	-3	-5	-6	-4
Tuffgard	-6	-4	-2	-5	+1	-4
Tuffgard,steel back	-6	-4	-5	-6	-9	-5

[1]Gates data with coal was extrapolated. All test runs were below 400 tons per hour.

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1. INTRODUCTION

Vibrating screens, among other equipment in mining and quarrying operations, have been shown to be a major noise source. Recent studies conducted under contract to the Bureau of Mines (Contracts #HO133027[1] and #HO144079[2]) indicate that noise levels of this equipment range from 95 to 103 dBA. The conclusions drawn from these studies is that screen noise emissions must be reduced to assure acceptable sound levels within the plant.

In order to install noise reduction treatments on screens, it is important to know how the treatments alter the performance of the screen, and whether or not the treatments have sufficient life. The purpose of this program was to demonstrate noise abatement technology for vibrating screens by extending prior development work performed by Allis-Chalmers during the four years prior to the contract award. In particular, acoustic and screening performance of non-metallic decks was established and a prototype noise-abated Low-Head screen was demonstrated and life tested.

The program was conducted jointly by the Crushing and Screening Equipment Division and the Advanced Technology Center (ATC) of Allis-Chalmers. Experimentation was performed at the ATC facilities in West Allis, Wisconsin and the ATC Development Lab in Oak Creek, Wisconsin.

2. OBJECTIVES

Three specific objectives were defined for this program:

- Establish noise levels of six commercial non-metallic decks and a steel wire cloth deck, operating with three different materials being processed.
- Establish screening performance with the above combinations.
- Fabricate a prototype noise abated Low-Head screen and demonstrate a screen-only sound level of 82 dBA. Demonstrate treatment life to 5000 hours.

All objectives were completed as planned.

3. DESCRIPTION OF TEST STANDS

3.1 Deck Test Stand

A sketch of the deck test stand is shown in Figure 1. The material system forms a closed loop, since the test material is returned to the hopper. The same batch of material runs through the system many times during one test. The major advantage of the closed loop material system is that an extremely large quantity of material is not needed to run a ten

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1 Coal Cleaning Plant Noise and Its Control, BuMines OFR 44-74.

2 Noise Control in Surface Mining Facilities: Chutes and Screens, BuMines OFR 64-76 and
Practical Reduction of Noise From Chutes and Screens in Coal Cleaning Plants, BuMines OFR 59-77.

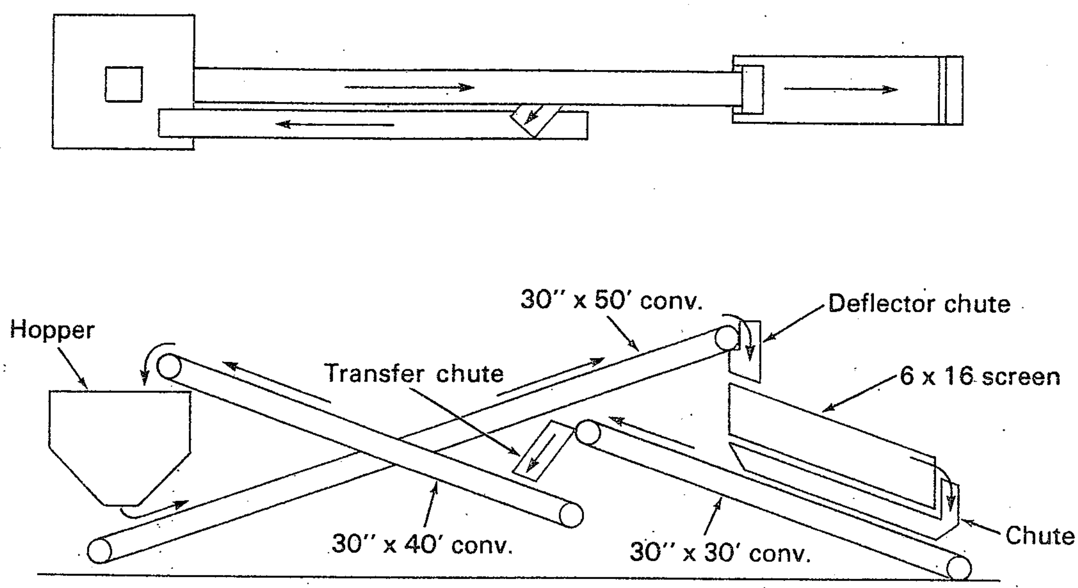

FIGURE 1. — *Sketch of deck test stand*

minute test, as would be the case with an open loop system. The problems of mixing, and loading the samples are eliminated with the closed loop. Material flows out the bottom of the hopper onto the 30 inch by 50 foot conveyor. An adjustable gate at the bottom of the hopper controls the flow. The material travels up the 50 foot conveyor and onto the screen. A deflector on the top of the conveyor ensures that the flow of material onto the screen is vertical, and helps to distribute the flow over the screen width. Undersize material and oversize material are recombined by a chute under the screen and directed onto a 30 inch by 30 foot conveyor. A transfer chute diverts the material to one side and onto a 30 inch by 40 foot conveyor which returns the material to the hopper. All surfaces which the test material may strike were lined with rubber. Photographs of the test stand are shown in Figures 2 and 3.

The test stand was located on a former free-field vehicle pass-by test site. The site consisted of a concrete runway with a measuring triangle attached by its base to the center of the runway. The screen is located on the triangle and the hopper and conveyors are located down one of the runways.

The screen used for the deck tests was an Allis-Chalmers 6 x 16 DD Ripl-Flow screen, equipped with a 4-4 mechanism and operating at 900 revolutions per minute. Before the start of testing the lower deck support framework was removed to make a single deck screen. For all tests the feedbox, discharge lip, center bars, and clamp bars were rubber lined.

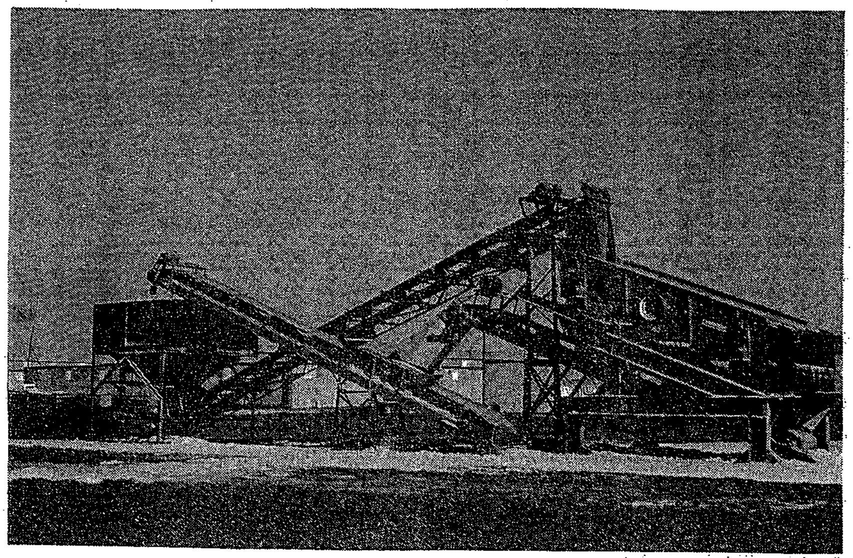

FIGURE 2. - Deck test stand, looking east.

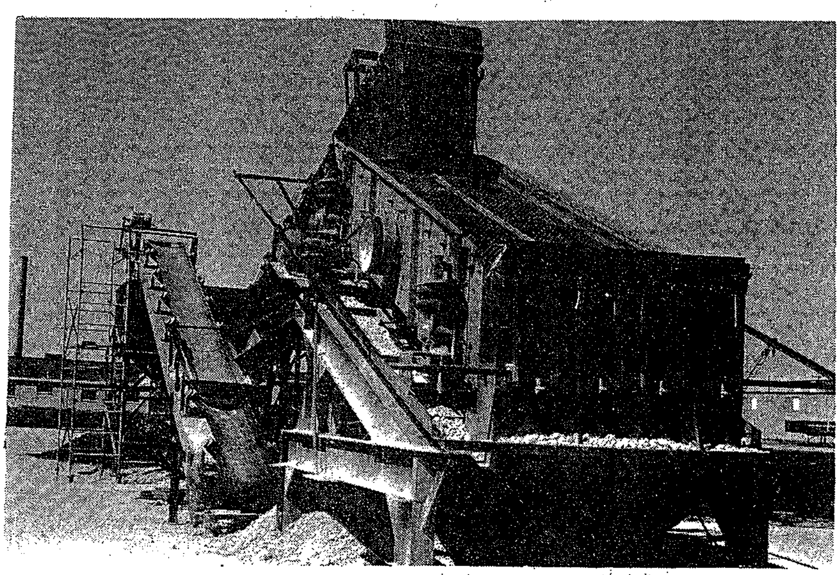

FIGURE 3. - Deck test stand, looking north.

At the start of testing several problems became evident quickly. The flow rate was being determined by stopping the 40 foot conveyor while loaded, and removing and weighing a 20 foot long sample of material. In order to do this, a nut was welded onto the input shaft of the conveyor speed reducer, and the material was cranked off, by hand, via a chute into a barrel. This proved to be both tedious and inaccurate, since the sample taken amounted to 2 seconds out of a 10 minute data run. The solution was to install a load cell system, Figure 4, which supported the 40 foot conveyor and using an ocillograph to constantly record the load over the test period. An average load over the duration of the test could then be easily obtained. A speed pick-up was also installed at the same time as a double check on the belt speed.

The second problem involved locating and moving the microphones. In the past, the microphones were supported by a tripod stand which had to be moved by hand to the next location. In addition, since the screen was mounted on an angle, the microphone also had to be lowered each time. The microphone stands also had a tendency to be knocked over by stray rocks. As a solution, two angle iron tracks were attached on either side of the stand, and the microphone was mounted to a sliding carriage. Detents in the track at the microphone location properly and repeatably positioned the microphone, even in conditions of high dust.

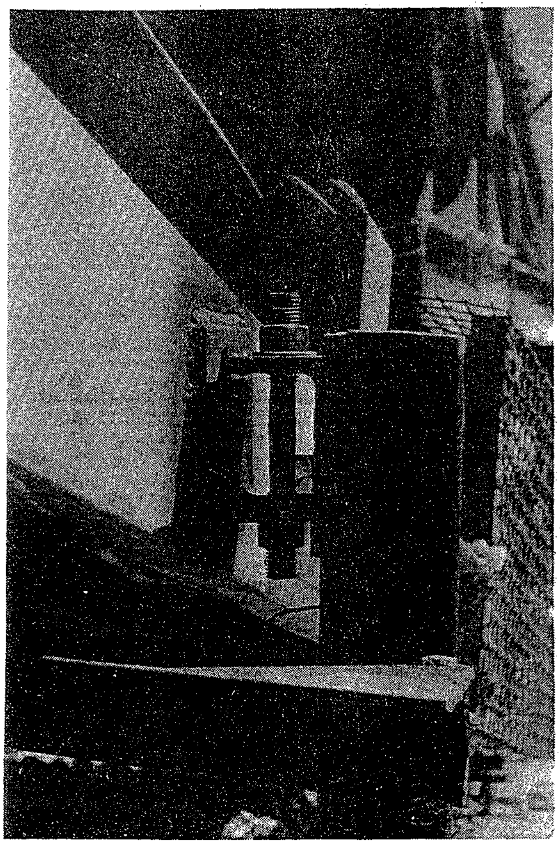

FIGURE 4. - Load cell.

The third problem involved sampling the top deck discharge for the efficiency measurement. Formerly, a shovel was used to catch the material as it fell off the top deck. This procedure was not repeatable, so four-1 foot wide sample chutes were installed in the chute at the end of the screen, Figure 5. These were flipped into the flow one at a time while the microphones were being moved. One-quarter of the total sample was taken from each chute.

Material was added to the system by loading it onto the 40 foot conveyor. Material was removed by extending the transfer chute which then dumped the material on the ground.

3.2 Low-Head Test Stand

The Low-Head test stand was located down the other runway from the deck test stand. This test stand, like the deck test stand was free-field. The two test stands were far enough apart so that there was no problem with interference during sound tests on either stand. The stand itself consisted of two parallel base H-beams, with side braces, anchored to the concrete. Spring bases were then bolted to the beams. The motor support framework consisted of three pieces; two H-beam vertical supports and an angle iron cross-piece. The bottoms of the verticle H-beams had flanges attached which were bolted to the parallel base H-beams. The angle iron cross-piece was bolted to the vertical H-beams and the motor was then attached to the cross beam. Since the tests were conducted without material, no conveyors or chutework were required. The completed test stand is shown in Figure 6.

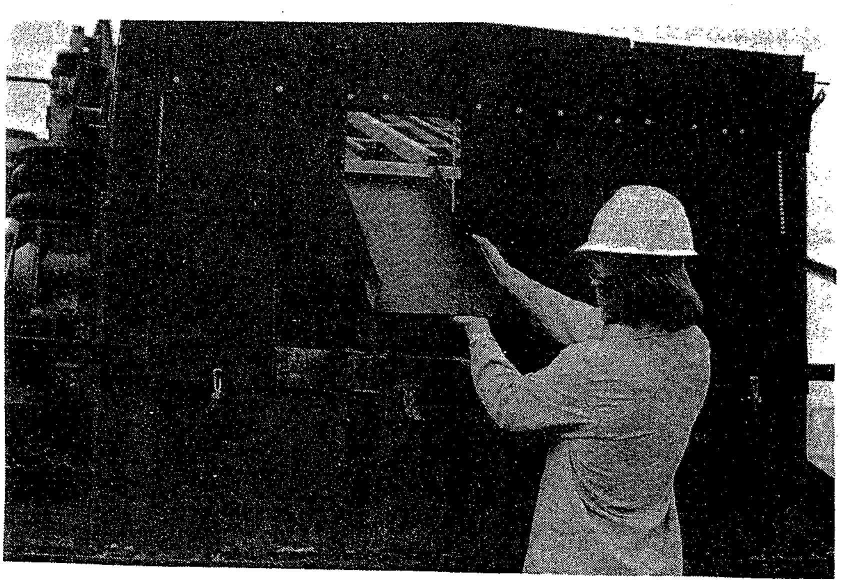

FIGURE 5. - Efficiency sampling chutes.

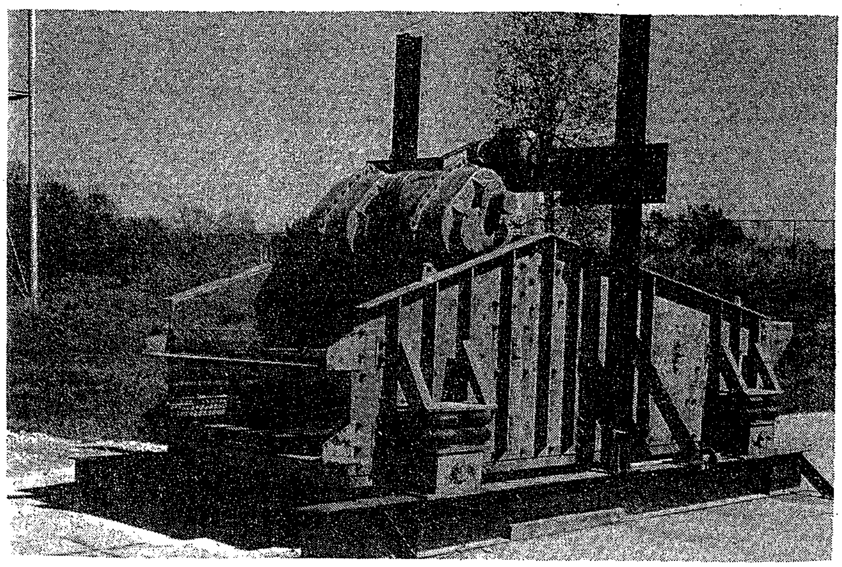

FIGURE 6. - Low-Head test stand.

The reason for the bolt together construction of the stand was that the screen had to be taken into the building many times for installation of new sideplates or mechanism isolators. The following procedure was used to bring the screen into the building: 1) The three piece motor support was removed with a fork lift, 2) the screen was lifted by two forklifts, one at either end, and the air springs were removed, 3) the screen was moved out from between the parallel base H-beams, and 4) a third, larger forklift then picked up the screen and brought it into the building.

The screen used for testing was an Allis-Chalmers 6 x 16 DD low-Head Screen, complete with a feedbox and discharge lips. The drive mechanisms were twin 4's equipped with E counterweights. Decks on the screen were a 1-1/4 inch steel wire cloth on top and a .5 millimeter profile deck on the bottom. The drive speed was 950 revolutions per minute. The usual drive speed for this particular screen is 900 revolutions per minute. The higher speed develops more throw from higher generated force, and because of the increased force, more noise. Allis-Chalmers had previously tested mechanism isolators under a company funded project. The approach under this contract was to determine whether the isolators worked under higher force conditions.

4. DECK TESTS

4.1 Introduction

The major source of noise when screening a hard material, such as coal, dolomite and granite, is the material being screened. One proven method of reducing this noise source is through the use of non-metallic decks. At present, there was a lack of applications information on the non-metallic decks. The purpose of this phase of the contract was to measure the performance of the non-metallic decks in terms of noise abatement and efficiency.

4.2 Deck Specifications

A total of seven decks were tested, consisting of three different types: 1) Resilient, 2) resilient clad steel and 3) steel wire cloth. The dimensional and material data for each deck is contained in Table 2. All decks are commercially available decks and were ordered for 1-1/4 inch separation. The 1-1/4 inch size was chosen because two decks were on hand before this program was started, and it was in the size range of decks most commonly used. As can be seen in the table, all hole sizes on the top surface of the decks are not exactly 1-1/4 inch square or the equivalent 1-1/2 inch round. One explanation for the smaller hole size is that since the top surfaces of the non-metallic decks are resilient a stone of larger than hole size could be forced through. Some of the decks have tapered holes which would increase the possibility of a stone being forced through, since the required force would decrease after passing through the upper section. Whether the differences in hole sizes was done intentionally or whether it is a result of errors in the manufacturing process is not known.

All decks tested had approximately 50 percent open area, including the wire cloth deck. The material system did not have the capacity to feed a deck with more open area (720+ tons per hour required), and for the comparisons being made, the 50 percent open area wire deck was selected.

4.3 Material Specifications

Three different materials were tested, covering a range of hardness: coal, dolomite, and granite. The coal used was anthricite coal from the Mammoth Vein, Pottsville, Pennsylvania, and was obtained from a Milwaukee, Wisconsin coal dealer. The granite was trucked to Milwaukee from a quarry near the city of Wausau in north-central Wisconsin. The dolomite was obtained from a local Milwaukee quarry.

During testing, the same type of material was left in the system while all decks were tested. New larger size material, of approximately 1-1/2 inch by 3 inch size, was added when the material in the hopper was getting low. Material was lost as dust, which blew away, and through a hole in the chutework beneath the screen, through which fines were lost. The larger pieces degraded with time and running. Samples removed for efficiency or sieve analysis were returned to the system.

TABLE 2. - Deck specifications

Deck	Hole shape	Hole alignment	Top surface hole size, inches	Bottom suface hole size, inches	Center to center, distance, inches	Top surface material	Total thickness, inches	Backing	
								Material	Thickness, inches
Steel wire cloth	Square	Straight	1-1/4	--	1-3/4	Steel	1	--	--
Gates	Round	Staggered	1-1/2	1-1/2	2	Rubber	5/8	Steel	1/4
Goodrich	Square	Staggered	1-1/16 - 1-1/4	1-3/8	1.81	Rubber	9/16 - 3/4	UHMWPE[1]	3/8 - 9/16
Linatex	Round	Staggered	1-9/16	1-5/8	2	Rubber	5/8	Steel	1/4
Trelleborg	Square	Straight	~1-3/8 (35mm)	~1-3/8 (35mm)	~2-3/32 (53mm)	Rubber	~5/8 (15mm)	--	--
Tuffgard	Round	Staggered	1-9/16 - 1-5/8	1-5/8	2	Urethane	5/8	--	--
Tuffgard	Round	Staggered	1-3/8	1-5/8	2	Urethane	3/4	Steel[2]	1/4

[1]Ultra high molecular weight polyethylene
[2]There is 1/8 inch layer of urethane beneath the steel

Sieve series analyses were taken at intervals during the testing. The purpose of the sieve analyses was to make sure that the same size distribution for each material was used during tests of all decks. The samples for the sieve analyses were taken by stopping the 40 foot conveyor with a load and then cranking off a drum of material. These were then analyzed using a Gilson screen. Results of these analyses, numbered in chronological order, for the three materials during the testing period is shown in Figures 7, 8, and 9.

The material was always run dry. If it had rained, the material system was run until the material became dry.

4.4 Test Procedure

A sketch of the microphone locations is shown in Figure 10. The required sound tests were run according to Allis-Chalmers' Proposed Standard Method for Measuring Sound from Vibrating Screens, Appendix A. When Allis-Chalmers began conducting noise tests on screens, no standard test method existed. Allis-Chalmers wrote a test procedure for screens, based loosely on NMTBA Noise Measurement Techniques[3]. Position 1 was not run because line of sight to the screen was blocked by the discharge chute. Position 3 was not run because of possible reflections from the 30 and 50 foot conveyors. The noise data acquisition system consisted two Bruel and Kjaer 4133 microphones, using Nagra-Kudelski preamplifiers. The noise data was recorded on a Nagra IV-SJ tape recorder.

The flow measuring system consisted of four strain gage load cell bolts. Signal conditioning was accomplished using a Hawkeye 1801 Amplifier and a low pass filter set to remove the non-DC component of the signals. The four signals were recorded on a Honeywell 1508 light beam oscilograph. The magnetic speed pick-up signal was counted by a Monsanto 1048 counter.

The test was started by checking the material level in the hopper, and filling if necessary. The microphones were mounted on the track and the sound system was calibrated. The load cell system was zeroed and the calibration was checked. The conveyors and the screen were turned on and the hopper gate was opened a measured distance to obtain the required flow. Once the material flow reached near steady state, Figures 11, 12 and 13, the oscillograph was started and the first two microphone positions were recorded (note microphones on tracks in Figures 11, 12 and 13). While the microphones were being moved, the first efficiency sample was taken. This procedure was repeated until all ten microphone positions were recorded and the four efficiency samples were taken. Several times during the test the flow system was checked and the conveyor speed written on the oscillograph paper. At the end of the test, if a sieve analysis was to be taken, the hopper gate was closed and the conveyors stopped with a load. The required sample was then removed from the 40 foot conveyor.

[3] National Machine Tool Builders' Association, June 1970

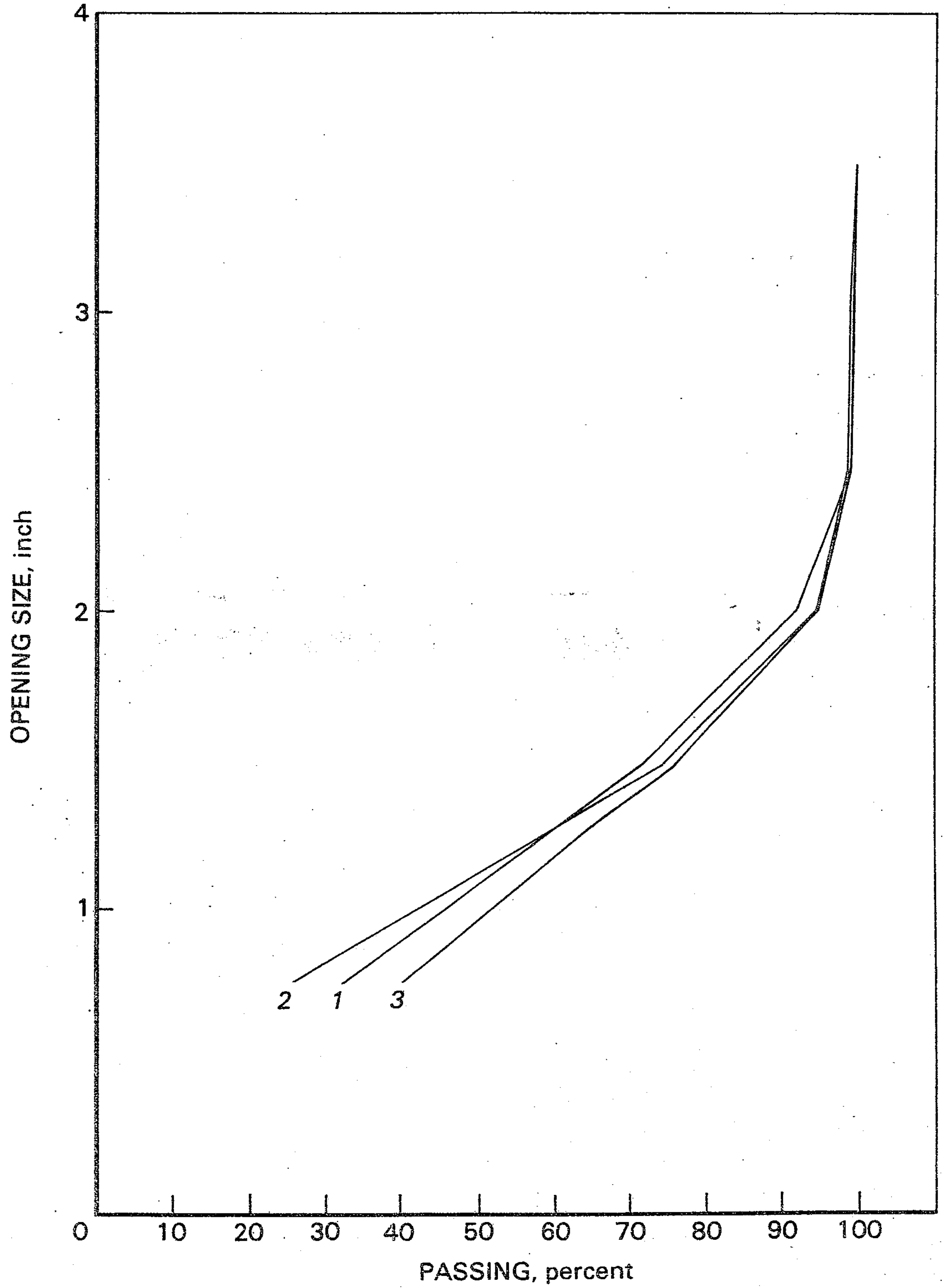

FIGURE 7. — *Coal sieve analysis*

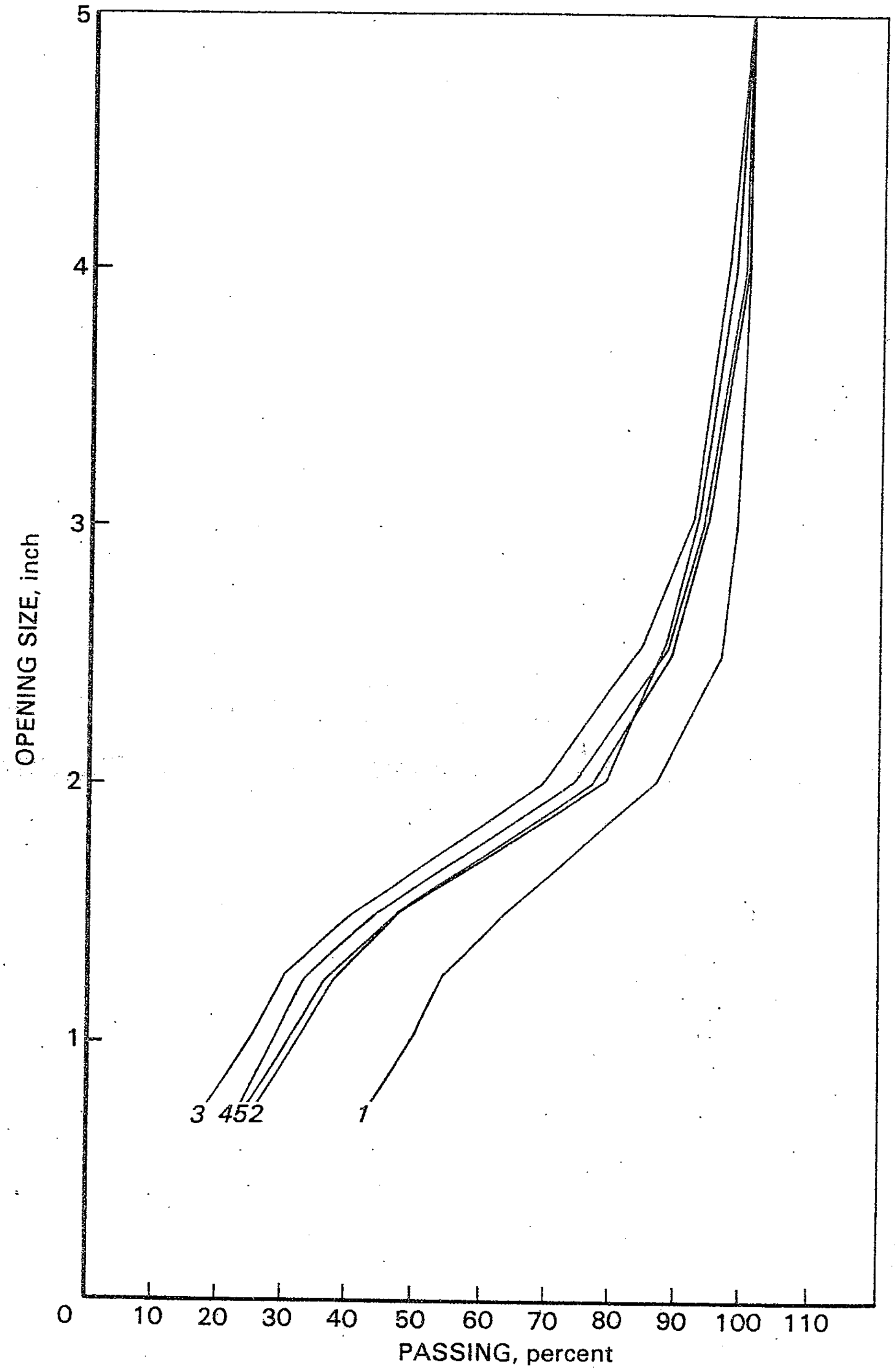

FIGURE 8. — *Granite sieve analysis*

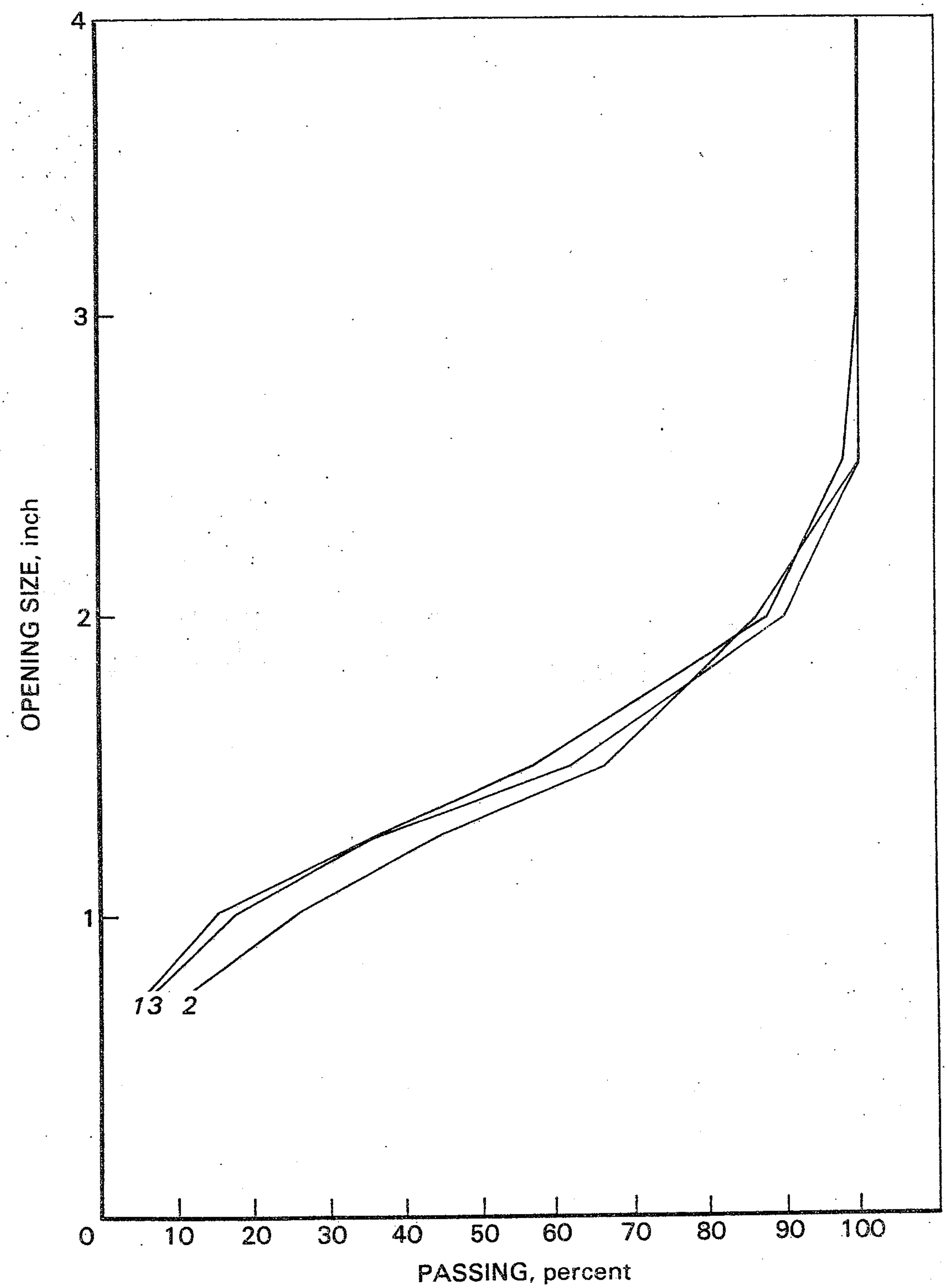

FIGURE 9. — *Dolomite sieve analysis*

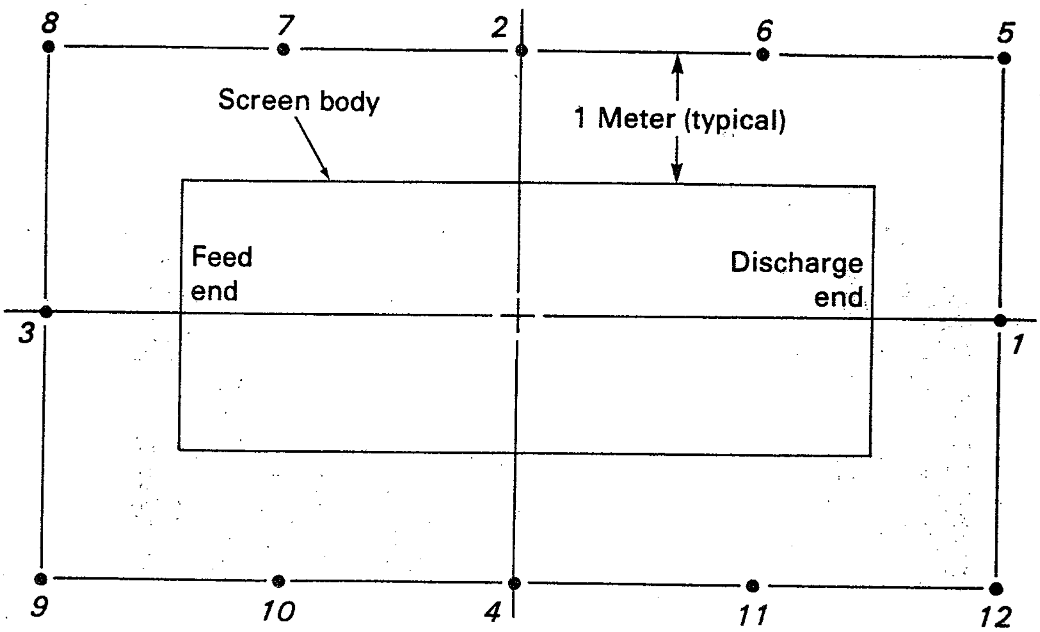

FIGURE 10. — *Microphone locations*

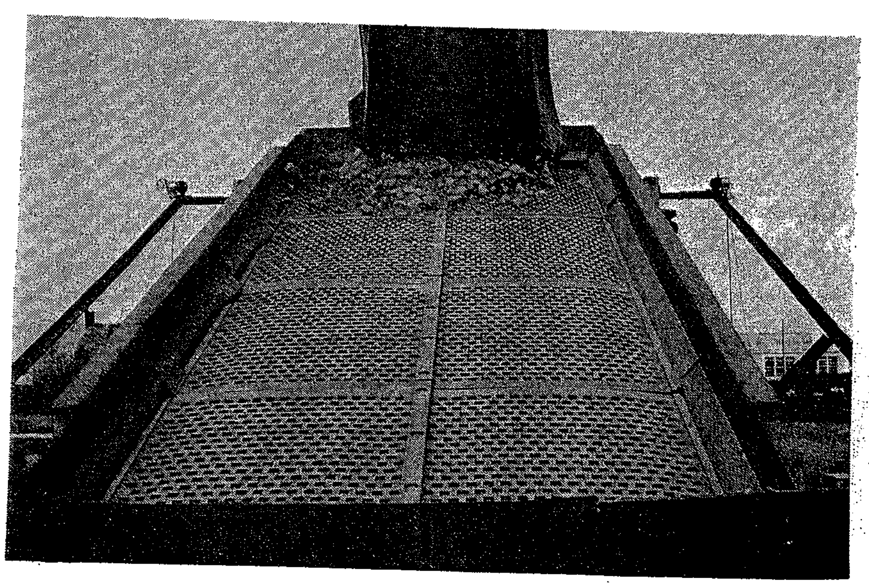

FIGURE 11. - Deck at start-up.

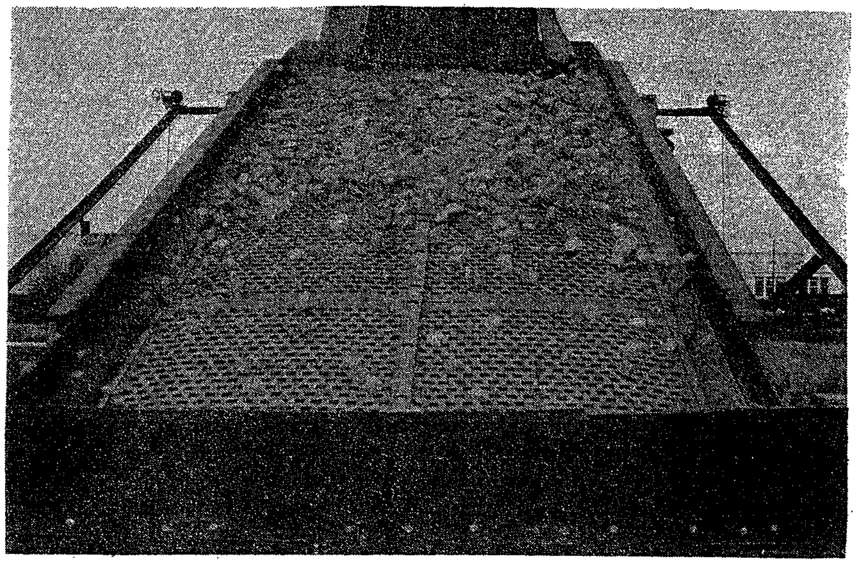

FIGURE 12. - Deck before stabilization.

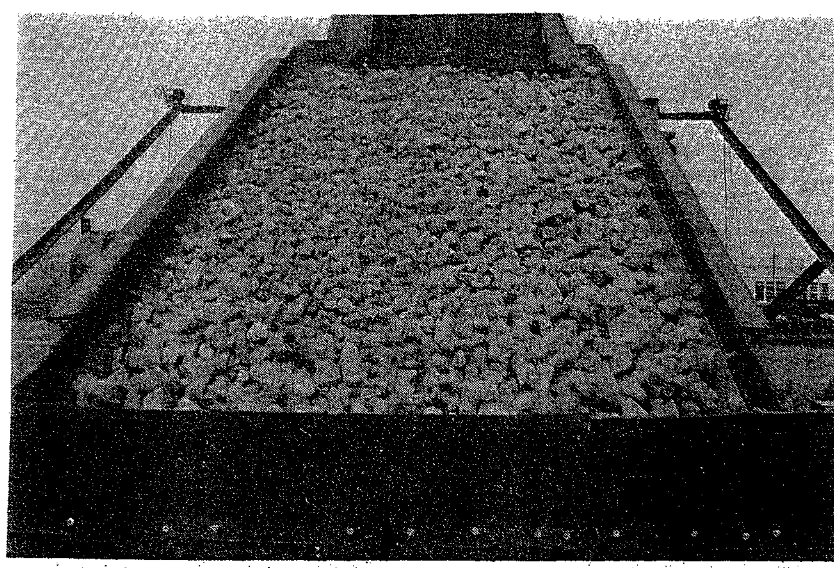

FIGURE 13. - Deck Stabilized.

The hopper was checked and the procedure was repeated at different flows until four tests had been run with the particular deck. The calibration of the sound and flow system was checked at the end of the four tests. The deck was then changed, and the whole procedure was repeated until all decks had been run. The hopper was then cleaned out and the next material loaded.[4]

The tape recorded sound data was analyzed using a General Radio 1933 sound level meter. The ten microphone positions were averaged to obtain one number, the average sound pressure level. The average values of the four load cell traces were summed to obtain the total load on the conveyor. The flow rate was calculated from the following formula:

$$F = \frac{C \times L \times V \times .03}{D} \qquad (1)$$

Where F = Flow rate (tons per hour)
C = Correction factor (.74)
L = Summed load cell value (pounds)
V = Belt speed (feet per minute)
D = Loaded belt length (32.3 feet)
0.3 = Conversion factor, pounds to tons, minutes to hours

The correction factor, C, was necessary for two reasons: 1) the material falling onto the conveyor from the transfer chute caused a dynamic load in addition to the static (weight) load, and 2) the transfer chute delivered the material perpendicular to the belt travel direction, which caused a build-up while the material was changing direction. The value of the correction factor was obtained by comparing the amount of material evenly distributed on the belt when sieve analyses were taken to the value obtained (for the same weight) from the load cells.

Efficiencies were obtained from the samples taken off the deck discharge. The samples were separated at 1-1/4 inch by a Gilson screen. The following formula was used to calculate the efficiency:

$$E = (1 - U/W) \times 100 \qquad (2)$$

Where E = Efficiency (percent)
U = Weight of undersize in sample (pounds)
W = Total weight of sample (pounds)

4.5 Test Results

All tests run (four per each of the seven decks), for the three materials are summarized in Tables 3, 4, and 5. The data has also been plotted on the graphs in Figures 14, 15, and 16. The lines for the decks (sound and efficiency) were obtained by determining the slope of a line for

[4] The exception to this procedure was the Goodrich deck, which arrived late, after the other six decks had already been tested.

TABLE 3. - Deck test results with coal

Deck	Flow, tons per hour	Efficiency, percent	Average sound pressure level, dBA
Steel wire cloth	367	68.2	99.2
	404	73.0	100.2
	424	78.1	101.4
	467	73.3	100.2
Gates (steel back)	304	69.2	94.6
	323	78.5	94.6
	327	67.8	95.0
	343	78.4	94.6
Goodrich	330	58.6	94.4
	338	67.6	94.3
	343	66.9	94.4
	501	63.0	93.9
Linatex (steel back)	321	74.2	97.0
	371	59.3	97.4
	383	66.6	97.6
	449	80.2	96.1
Trelleborg	339	60.3	95.6
	385	65.2	95.3
	394	69.1	95.4
	403	70.9	95.2
Tuffgard	414	71.5	97.0
	418	74.2	96.4
	436	72.8	96.7
	466	83.4	96.4
Tuffgard (steel back)	338	56.9	94.4
	360	59.2	94.6
	377	67.7	94.7
	393	65.5	95.0

TABLE 4. - Deck test results with granite

Deck	Flow, tons per hour	Efficiency, percent	Average sound pressure level, dBA
Steel wire cloth	442	92.5	106.0
	553	94.7	106.2
	584	94.5	106.5
	614	91.9	104.6
Gates (steel back)	344	91.8	99.2
	460	93.8	99.6
	492	92.9	100.0
	561	93.6	100.4
Goodrich	354	89.4	100.8
	387	88.1	100.4
	605	91.5	99.6
	668	89.1	99.3
Linatex (steel back)	386	92.5	104.2
	416	91.4	104.9
	445	90.1	103.9
	508	92.5	104.4
Trelleborg	474	91.9	100.3
	548	91.7	100.0
	555	90.7	100.8
	572	90.9	100.8
Tuffgard	407	87.9	100.4
	412	92.4	100.2
	464	93.8	99.9
	516	93.4	101.0
Tuffgard (steel back)	412	89.4	100.0
	540	89.4	98.8
	580	88.5	100.6
	585	89.5	99.4

TABLE 5. - Deck test results with dolomite

Deck	Flow, tons per hour	Efficiency, percent	Average sound pressure level, dBA
Steel wire cloth	480	82.3	105.1
	493	85.6	105.1
	517	81.8	105.3
	585	83.0	104.8
Gates (steel back)	489	79.1	98.3
	536	79.3	98.0
	552	81.0	98.0
	568	85.6	97.6
Goodrich	388	77.3	98.2
	445	81.3	98.9
	492	81.5	98.9
	500	81.1	99.8
Linatex (steel back)	437	82.5	99.9
	467	84.9	100.5
	501	83.3	101.3
	556	83.5	101.5
Trelleborg	480	77.2	100.6
	537	77.9	101.2
	584	75.1	101.3
	686	80.3	100.9
Tuffgard	531	69.6	101.6
	563	76.5	101.6
	565	77.5	102.0
	584	83.7	101.9
Tuffgard (steel back)	511	69.6	101.6
	547	77.5	102.0
	604	83.7	101.9
	653	76.5	101.6

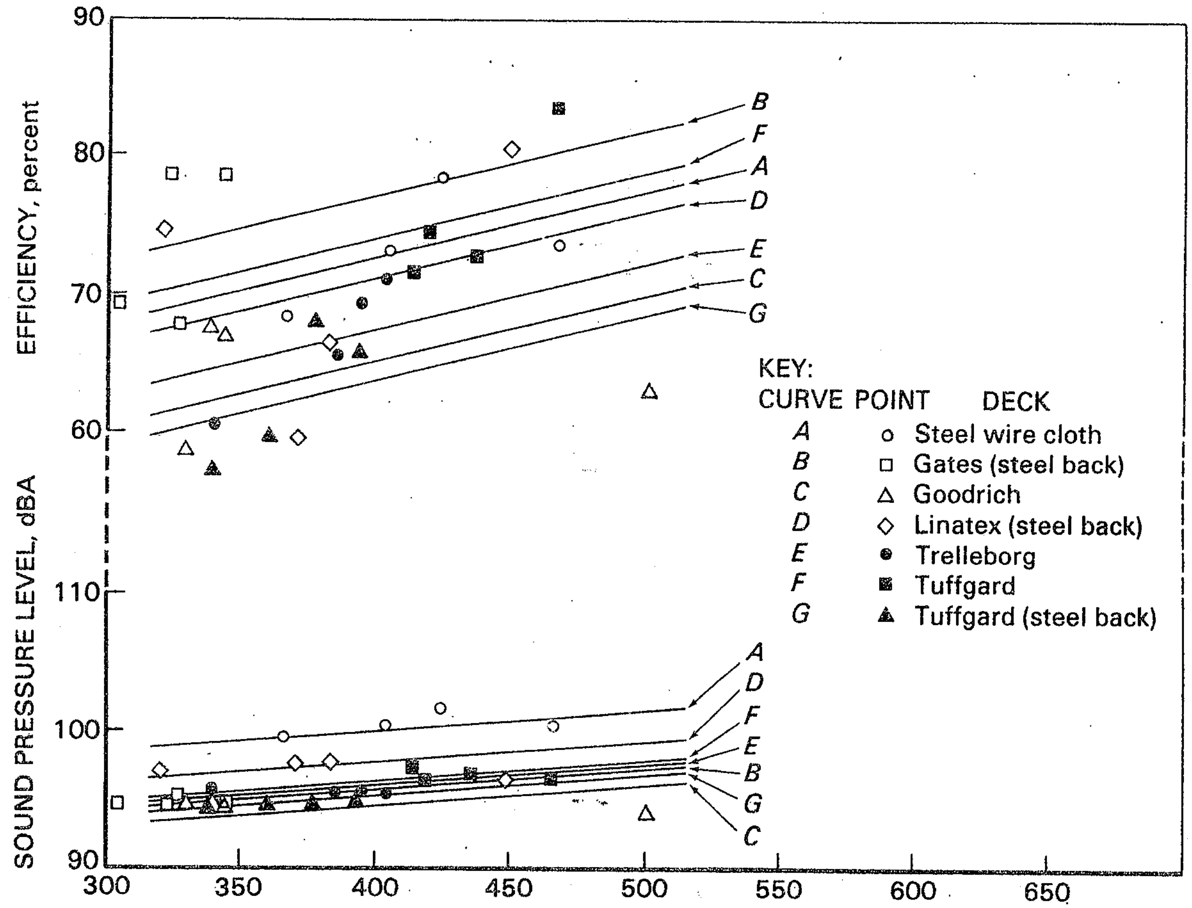

FIGURE 14. — *Coal deck test results.*

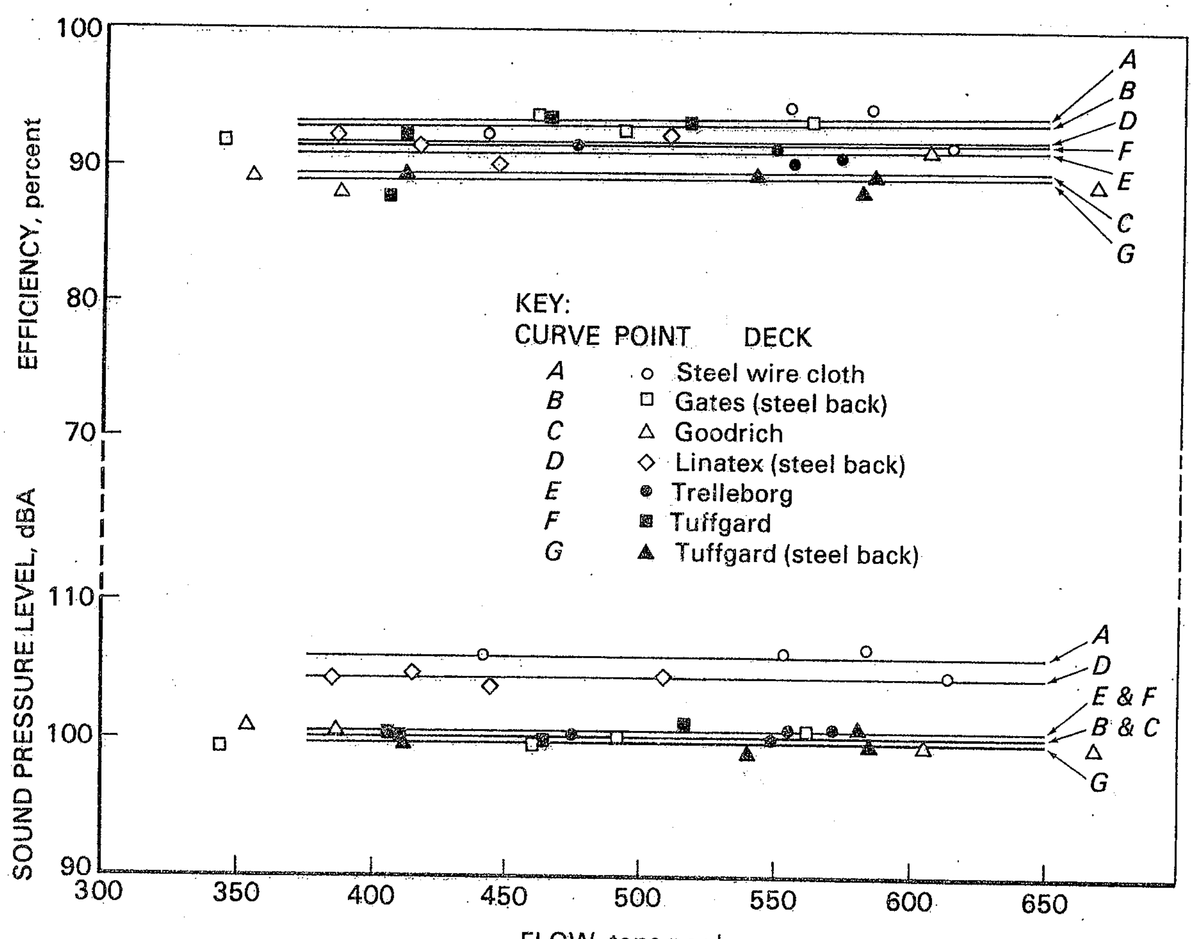

FIGURE 15. — *Granite deck test results.*

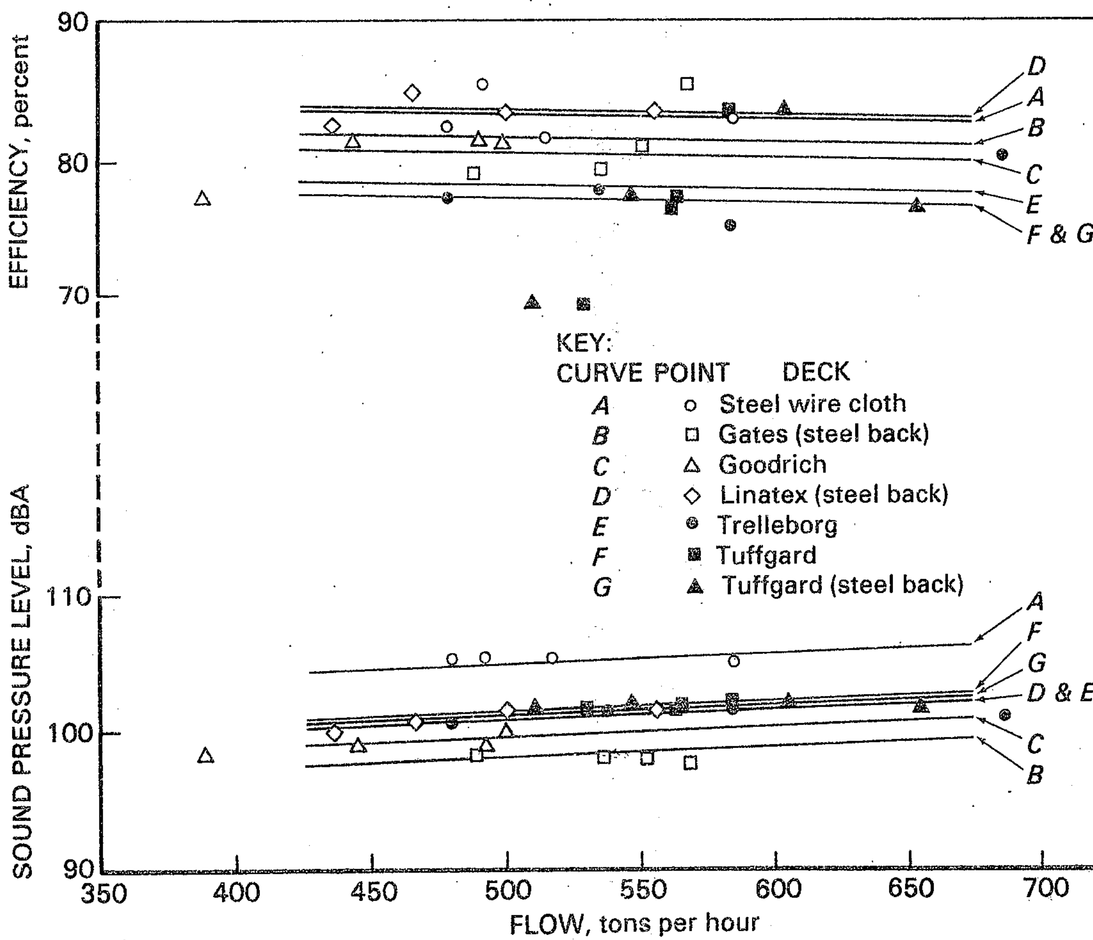

FIGURE 16. — *Dolomite deck test results.*

for all decks, with a particular material, and assuming that to be the slope of any individual deck. As can be seen from the plots, both the granite and the dolomite were run at near the maximum efficiency points. The coal, however, could not be run at a high enough flow rate to reach the maximum point. All materials were run at the maximum volume flow rate, as limited by the spill-off capacity of the conveyors. The coal, being less dense than the dolomite and granite, reached this point at a lower weight flow rate.

The non-metallic decks provide from 2 to 7 dBA noise reduction, but at a loss of from +1 to -10 percent in efficiency as compared to the steel wire cloth deck. The steel wire cloth deck tested had an open area of 50 percent. A standard wire cloth deck would have an open area of greater than 50 percent, and a larger capacity.

The standard screening efficiency theory predicts that the data should be an inverted parabolic curve when plotted. At flow rates above the maximum point, the number of particles would limit the chances of a particular particle falling through a hole. At flow rates below the maximum point, the individual particles are not confined as much by other particles and tend to bounce down the deck too fast. The efficiency data was plotted as a straight line, because over the small range of flows tested, a straight line was a good approximation of the parabola.

The standard theory also states that a maximum efficiency of 95 percent can be reached. The average efficiency for the granite is close to this, but the average efficiency for the dolomite was about 12 percent lower. An explanation for this would be that the granite was more spherical in shape, while the dolomite tended to have rectangular cross-sections. Any orientation of a spherical particle would pass through a hole, but a rectangular section would have to be turned correctly to fit.

For some of the decks, lines of different slopes could be plotted through the test efficiency points. Whether those slopes are true or not depends upon the accuracy of the individual points. Repeating material flow rates exactly was impossible once the hopper was closed. The hopper opening could never be reset at exactly the same point. As one test of accuracy, four different efficiency samples were taken at one flow rate. A difference of ±2 percent from the average was measured. Without many more data points, the exact shape of the individual curves cannot be determined, however the data does serve as a reasonable approximation.

Samples of the non-metallic decks[5] were placed in a salt spray bath[6] for 2500 hours. At the end of the test, none of the decks showed any degradation which would hurt their performance. The steel backing on the Gates,

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[5] Except for the Goodrich deck, which arrived late

[6] For a description of the salt spray bath, see section 5.3.2 Lab Tests.

Linatex and Tuffgard decks were rusted and pitted where exposed, but the steel to resilient surface bond had not separated. The samples were not, however, subjected to the abrasion and pounding the decks would see in an actual application.

5. LOW-HEAD ABATEMENT

5.1 Introduction

In addition to the material noise reduction testing, described in Section 4, noise abatement of the bare screen is also necessary. Two techniques were tested to reduce the noise of a bare screen; mechanism isolation and constrained layer damping of the sideplates. Damping may also have some benefit in reducing impact noise caused by the material.

Three series of tests were run on the mechanism isolators and the damping treatments: 1) Comparison tests of four damping treatments and the mechanism isolators to determine the noise reduction levels for the treatments. 2) Lab tests of samples of the treatments in a salt spray bath to determine their ability to withstand an accelerated corrosive environment. 3) A life test of mechanism isolators and one of the damping treatments to determine the ability of the treatments to withstand the continual shaking they are exposed to on a screen.

5.2 Treatment Descriptions

Noise from the sideplates of a screen is caused by the vibration of the steel which in turn causes the air around the steel to vibrate. These air vibrations are the noise noted by an observer. By damping the sideplates, the amplitude of the vibrations is reduced and is noted as a lower noise level.

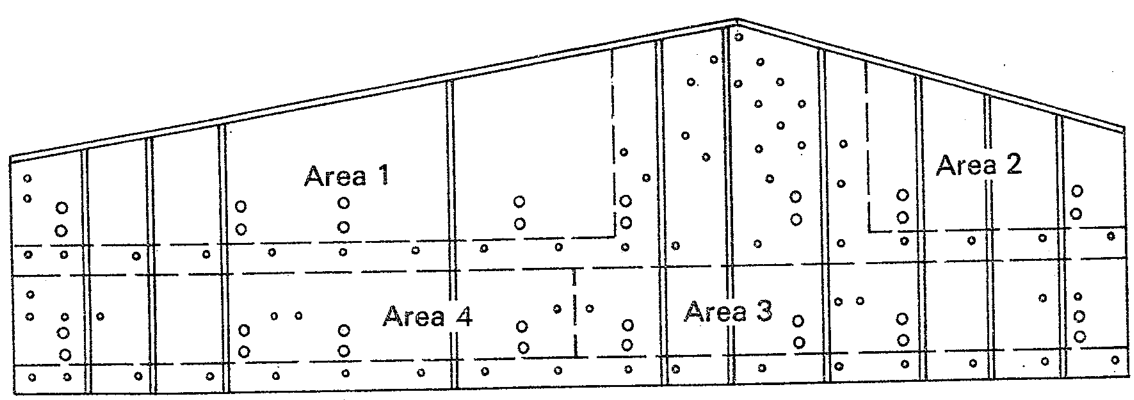
Constrained layer damping consists of a visco-elastic material, sandwiched between two layers of metal, one of which is the sideplate. As the metal vibrates, the metal actually is bending. The visco-elastic layer between the metal sheet acts as an energy absorber which reduces the amplitude of the vibrations and the noise.

In addition to the noise reduction properties, the requirements for the damping treatments were that they should be easy to install, low cost, low weight, and should have a good life in the screening environment. Technical discussions were held with vendors of constrained layer damping treatments on these criteria. The specifications for the four constrained layer damping treatments considered is shown in Table 6. In addition, a corrosion preventative coating Allis-Chalmers uses on some screens was tested. Since only a total of four treatments were to be tested, including the corrosion coating, the Soundcoat treatment was eliminated due to the weight of the secondary sheet required.

The areas of the sideplates covered by the damping treatments is shown in Figure 17. The damping treatments were applied to the inside surfaces, and were composed of four pieces. The areas not covered were where the two

TABLE 6. - Sideplate damping designs

Manufacturer	Visco-elastic material Type	Visco-elastic material Thickness, inches	Attachment method	Steel secondary sheet thickness
Antiphon	Tiger MPM	.020	Self-adhesive	11 gage
EAR	C-1002	.063	Bostik 7132	11 gage
Soundcoat	DYAD 606	.050	Bolt attachment	.250 inch
3-M	ISD 112	.008	3-M 1838	11 gage
Prufcoat (corrosion coating)	510-20	.010	Spray-on	none



Note: Damping panels are located on inside sideplate surface.

FIGURE 17. — *Damping treatment coverage.*

deck frames and the mechanism cross-beam were bolted in place. Total area coverage of the damping treatments on the sideplates was 66 percent. In addition, the feedbox and the back plate were also treated.

The mechanism isolator design is shown in Figure 18. The isolators are mounted between the drive mechanisms and the cross-beam, Figure 19. The theory of operation is that the isolators can be selected in design such that the forces at the drive frequency is passed to the screen with no attenuation and the forces at the higher harmonics of the drive frequency will then be attenuated (see Figure 20).

5.3 Test Procedure and Test Results

5.3.1 Comparison Tests

The first step was to install the damping treatments on the sideplates. New sideplates were obtained for these tests. The inside surfaces were sand-blasted clean and then wiped with a solvent to remove any trace of greases. The secondary sheets were obtained sheared to size and the required holes were drilled, Figure 21. Some of the holes were for screen structure bolts others were for additional clamping. One set of secondary sheets was sent to 3-M for installation of their visco-elastic layer.

The first set of sideplates was assembled using the Antiphon method. The visco-elastic material (which served as the adhesive) was mixed and applied to the sideplates in stripes, Figure 22. The stripe pattern was obtained by using an ordinary paint roller with sections of the "fuzz" removed. Shim washers (.020 inch thickness) were used around bolt holes to maintain the spacing, Figure 23. Clamping bolts and temporarily placed structural bolts were used to clamp the assembly during the cure period, Figure 24.

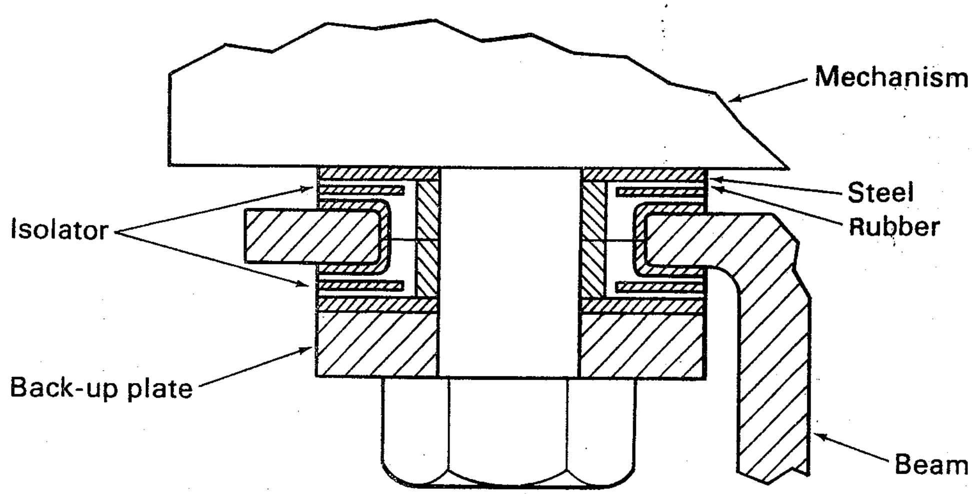


FIGURE 18. — *Mechanism isolator design.*

FIGURE 19. - Mechanism isolator installed.

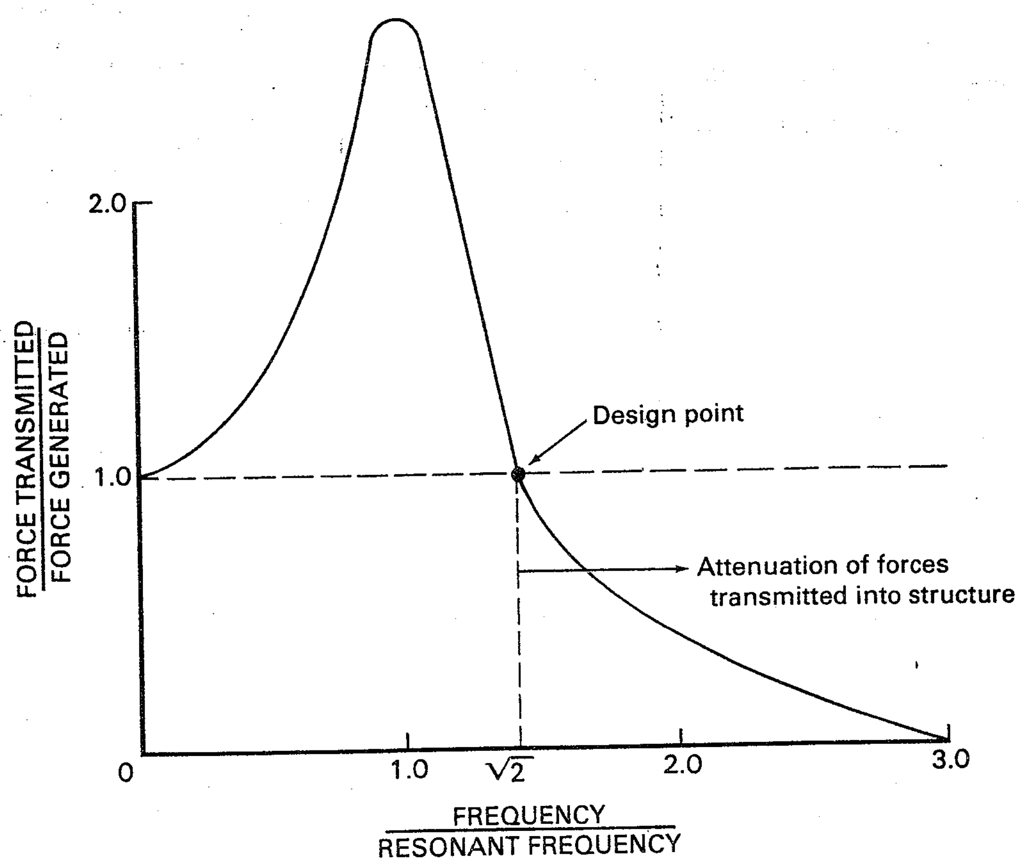


FIGURE 20. — *Mechanism isolator theory.*

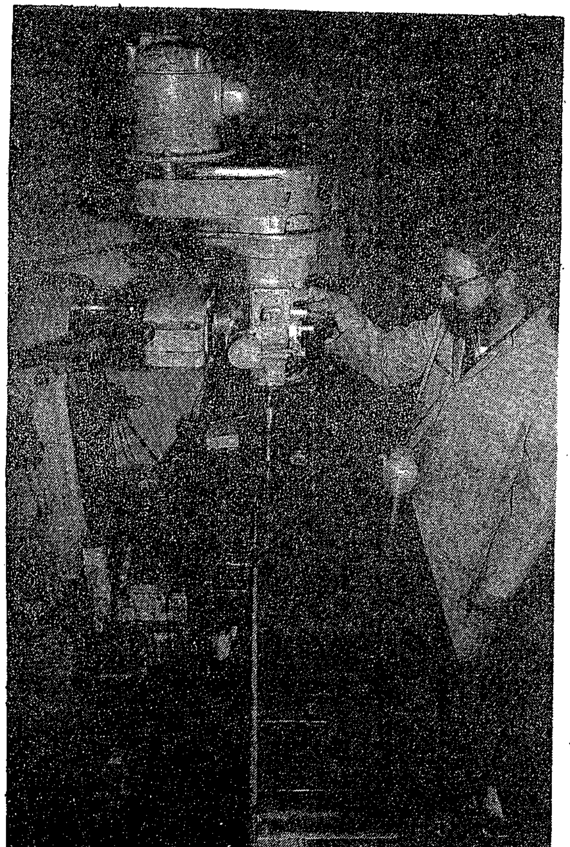


FIGURE 21. - Cutting holes in secondary sheets.

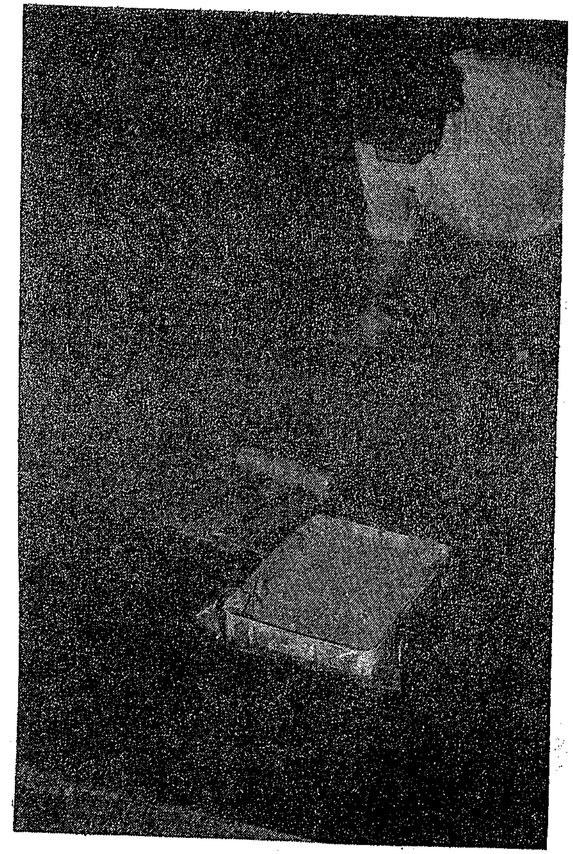


FIGURE 22. - Applying Antiphon damping treatment.

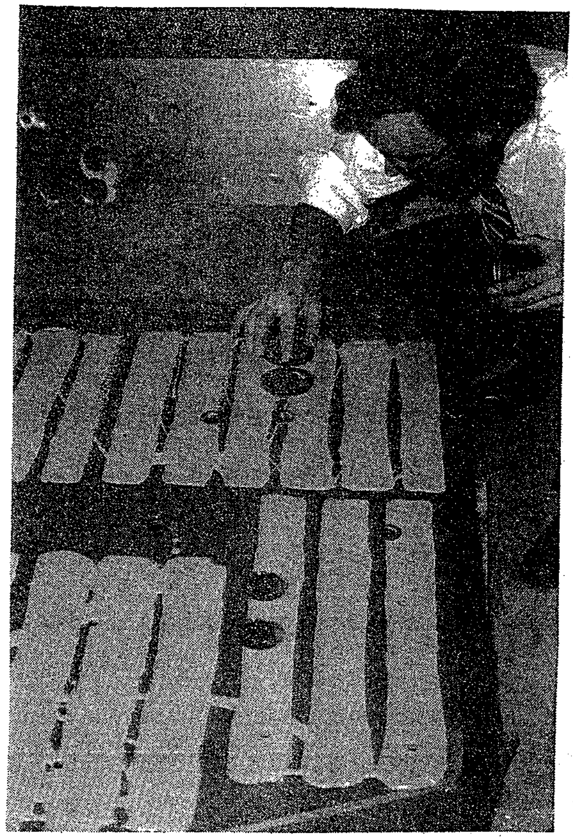


FIGURE 23. - Applying shim washers.

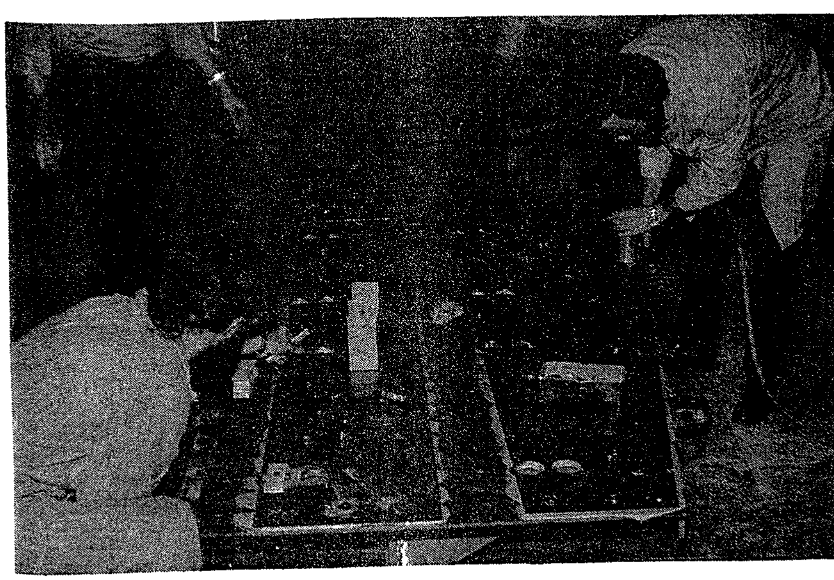


FIGURE 24. - Clamping assembly.

The second set of sideplates was assembled using the EAR method. In this case, the visco-elastic material was in sheet form, which was first attached to the secondary sheet, Figure 25, using a contact adhesive, and then the assembly was attached to the sideplate, using the same adhesive, Figure 26. Several layers of the contact adhesive were required to fill slight voids in the sideplates. Weights and clamping bolts were used to achieve a good bond.[7]

The last set of sideplates was assembled using the 3-M method. The secondary sheets arrived from 3-M with the visco-elastic material bonded. A filled epoxy adhesive was applied to the sideplates with a toothed trowel. The ridges left by the teeth allowed air to escape when a secondary sheet was applied. Bolts were then used to clamp the assembly. The edges had to be cleaned of epoxy to prevent the possibility of shorting the secondary sheet to the sideplate.

All three treatments were applied with the sideplates horizontal. However, the 3-M and EAR treatments could easily be applied in the vertical position. Antiphon treatment could also be done vertically, but it would require sealing at the edges to keep the visco-elastic material from slowly flowing out.

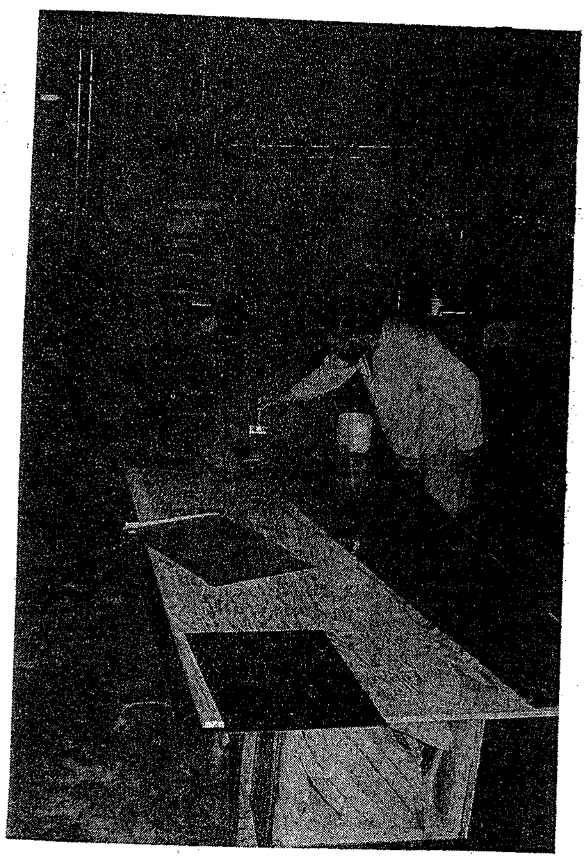


FIGURE 25. - Applying EAR damping treatment.

[7] EAR was conducting tests to determine an epoxy adhesive with void filling capabilities that is compatable with their visco-elastic material.

FIGURE 26. - Applying assembly to sideplate.

The microphone positions, Figure 10, used for the tests were based on Allis-Chalmers Proposed Standard Method for Measuring Sound from Vibrating Screens, Appendix A. The overall A-weighted sound is obtained by averaging all twelve locations. Instrumentation consisted of a General Radio 1933 sound level meter, ten foot extension cable, and a 1/2 inch 1962-9601 microphone. Calibration of the microphone was performed before and after the test. Also performed during each test was a measure of the loss factor of the sideplate. This was done using a Hewlett-Packard 5420 Fast Fourier Transform analyzer to obtain a force over accelerating transfer function and using the half-power bandwidth technique to obtain the loss factor. The force signal for the transfer function was obtained from a force transducer (PCB 208A03 transducer, PCB 480A power supply) on an impact hammer, and the acceleration signal was obtained from a BBN 508 accelerometer, and a BBN-P-20 power supply. The transfer function was done in real time and recorded on the 5420's data tape, and analyzed at a later time. A loss factor was calculated for each of the four areas of the sideplate that were covered by the damping treatments. The four numbers were then averaged to yield one value.

The testing began with a baseline test run with the standard sideplates. The screen was then brought into the building, Figure 27, where it was disassembled and the next set of sideplates was installed, Figure 28. The screen was then returned to the stand and another test was run. This was repeated until all sideplates were tested. The original sideplates were reinstalled and the corrosion coating was applied. The test results are summarized in Table 7. The baseline sound pressure level of the screen was 88.7 dBA.

FIGURE 27. - Bringing screen into building.

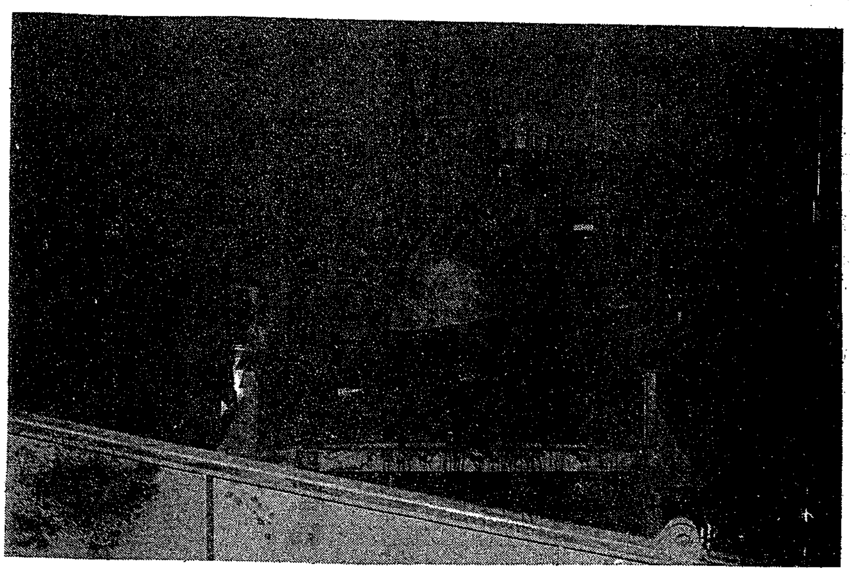


FIGURE 28. - Assembling screen with new sideplates.

Table 7. - Low-Head damping test results

Test description	Sound pressure level reduction from baseline, dBA	Loss factor
Baseline	---	.06
Antiphon	4.9	.12
EAR	4.7	.09
3-M	3.7	.12
Prufcoat	.5	.07

After all the sideplate damping comparison tests had been completed, the Antiphon treated sideplates and the mechanism isolators were installed and tested. The Antiphon treated sideplates were chosen for this test because they gave the largest reduction during the comparison tests and it was also the easiest damping treatment to assemble. On the first test, no change in sound level was obtained. Upon inspection of the isolators, it was noted that there was too much preload. This can be seen by eye because of the sandwich construction of the isolator, Figure 18, where the thin layers of rubber between the steel sheets bulge out at the edges when even slightly overloaded. If the isolators are overloaded, the design point on the curve in Figure 20 shifts to the left and instead of being attenuated, the harmonics of the drive frequency can actually be amplified. The preload of the isolators is controlled by the relative thickness of the cross-beam flange and the isolator set stack-up. Inserting .015 inch shim washers between the isolator halves reduced the preload. Upon retest, an additional 2.1 dBA reduction was obtained from the mechanism isolators. A total reduction of 7.0 dBA, from 88.7 to 81.7 dBA was obtained for the mechanism isolator-sideplate damping combination.

5.3.2 Lab Tests

The purpose of the lab tests was to note any severe degradation in performance with time. Lab tests consisted of deck, mechanism isolator, and tensile and loss factor damping samples placed in a salt spray bath (ASTM B117) at 95°F. The bath sprays a fine mist of solution into a closed chamber, creating a 100 percent relative humidity environment. The solution was mixed to duplicate an average composition of actual coal plant wash water analysis obtained from four samples from various areas of the United States. The coal plant wash water was considered to be the worst case chemically. The composition of the solution used is contained in Table 8. The solution contains a high percentage of salts and the pH is just slightly basic. The salt bath accelerates the degradation of the samples by a factor of at least ten. The damping tensile samples were made from a 4 inch by 1 inch by 5/16 inch steel bar glued to a 4 inch by 1 inch by 11 gage steel strip in a 2 inch by 1 inch bond area, using the particular damping treatment as the adhesive to form a tensile specimen, Figure 29. Three of each of the damping treatments were removed from the salt bath and tested every 500 hours for 2500 hours.[8] Test results are contained in Table 9.

TABLE 8. - Composition of salt spray solution, average chemical analysis of coal plant wash water

Chemical	Concentration, parts per million
Chlorides	1400
Sulfate	704
Bicarbonate	124
Carbonate	16
Sodium	1500
Calcium	653
Magnesium	46
Potasium	9.3
Aluminum	1.6
Ammonia nitrogen at N	2
pH	7.3

[8] The Soundcoat damping treatment was not tensile tested, since no adhesive is used during actual assembly.

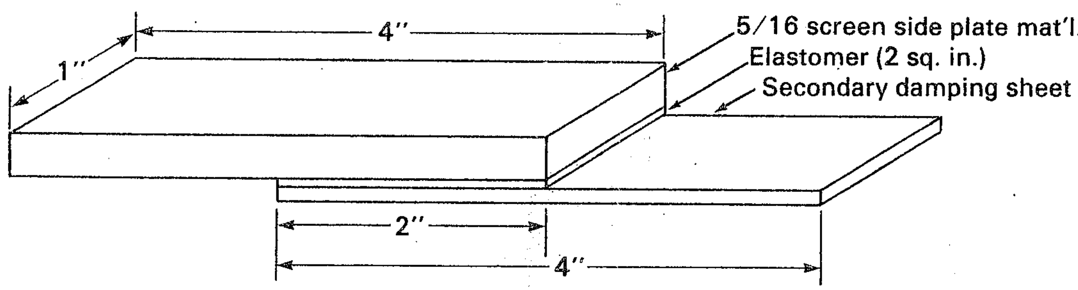


FIGURE 29. — *Damping tensile specimen.*

TABLE 9. - Damping tensile specimen test results

Test time, hours	Antiphon Tensile strength, pounds per square inch				Antiphon Bonding area, percent	EAR Tensile strength, pounds per square inch				EAR Bonding area, percent	3-M Tensile strength, pounds per square inch				3-M Bonding area, percent
	1	2	3	average		1	2	3	average		1	2	3	average	
0	36	280	72	129	100	104	156	131	130	100	34	56	58	49	100
500	19	173	40	77	90-95	85	82	93	87	40-70	29	31	36	32	70
1000	38	25	15	26	50	118	88	129	112	40-70	25	21	19	22	70
1500	26	31	32	30	30	72	68	53	64	30	26	25	24	25	70
2000	15.5	.5	16	11	20	47	58	41	49	30	22	20	22	21	60
2500	7	16	-[1]	11	20	-[1]	34	26	30	30	6	8	19	11	30

[1] Sample broke while being placed in test fixture.

Of the three treatments, the 3-M treatment, had the lowest strength at the start and would require more clamping bolts to prevent the panels in an actual installation from pulling loose. All of the treatments lost strength with time. At the end of testing both the 3-M and EAR treatments retained over 20 percent of the original bond strength. The Antiphon treatment had 8 percent of its original strength left. Since the test samples had a very small bond area of 2 square inches, and since rust penetrates from the edges, all treatments should have adequate adhesion life on the large damping panels used on the full size screen.

The loss factor samples consisted of an 8 inch by 8 inch by 5/16 plate, to represent the sidewall material, to which a 6 inch by 6 inch plate of secondary sheet material was bonded by the damping treatments. Three through bolts were used on each sample for clamping. Two samples of each damping treatment were made. One was placed in the salt bath, the other, the control, was left in room conditions. For the corrosion coat, the entire 5/16 inch thick plate was coated. The loss factor test procedure, described in section 5.2.1 was used to test both sets of samples every 500 hours. Figure 30 shows a sample during a loss factor test. It is important to remember that the purpose of these tests was to note any severe degradation of performance with time in either control or salt bath sample. Since the treatments were designed for the large area of the screen sideplate, comparisons in actual performance between different treatments can not be made. The test results are contained in Figure 31. Towards the end of the test, the plates in the salt bath were becoming extremely rusted, except for the corrosion coated plate. Discounting the last test, where the rust on the plates may have been influencing the data, once treated, the loss factors of all of the plates remained approximately constant. The samples were separated at the conclusion of testing. The remaining bond area is shown in Table 10.

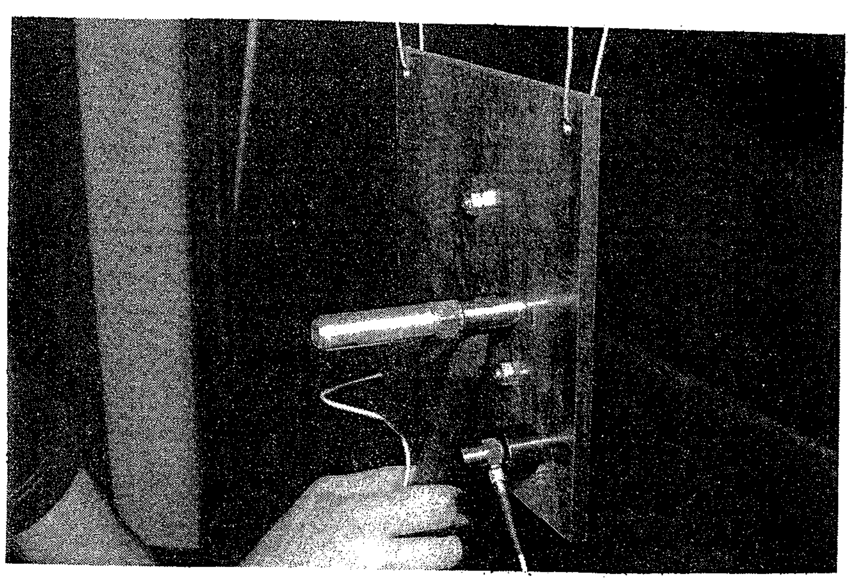


FIGURE 30. - Damping loss factor sample during test

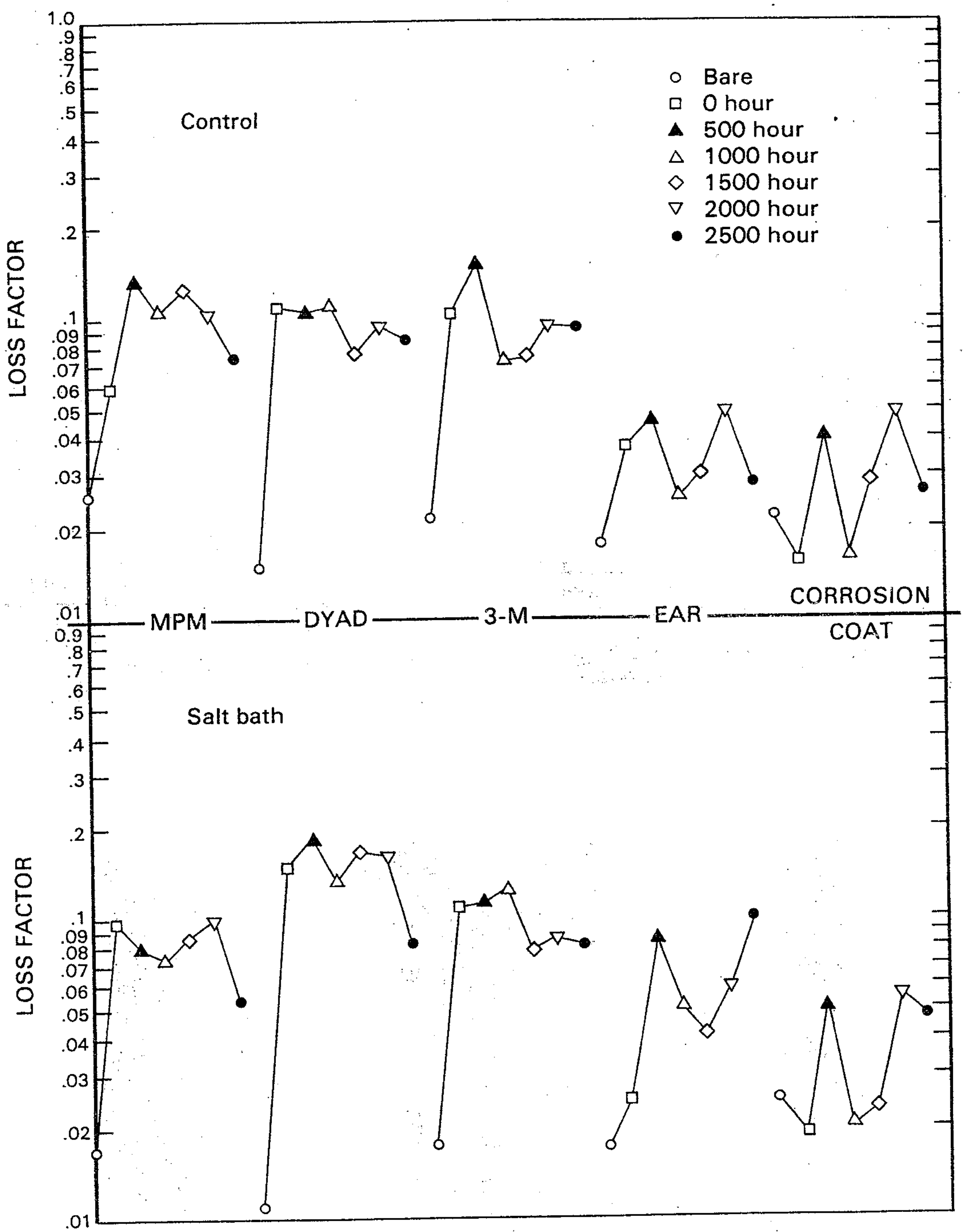


FIGURE 31. — Damping loss factor sample test results.

TABLE 10. - Remaining bond area of damping loss factor samples

Treatment	Bond area remaining after 2500 hours, percent	
	Control	Salt spray
Antiphon	100	22
EAR	100	35
3-M	100	30
Soundcoat	100	16
Prufcoat	100	100

A mechanism isolator was also placed in the salt bath for 3,000 hours. Although the exposed metal surfaces were pitted from rusting, the bond between the rubber and metal, and the rubber itself was undamaged.

5.3.3 Life Tests

The life tests consisted of running the treated screen for 5,000 hours to test the treatments for mechanical integrity and performance. The test was run without material. The life tests were run with the Antiphon treated sideplates, and the mechanism isolators installed. The Antiphon treatment was choosen for the life test because it gave the best sound reduction and was the easiest treatment to assemble. Sound and loss factor tests were conducted every 1,000 hours of operation. The test data is summarized in Table 11. As can be seen from the data the treated screen performed well over the 5,000 hour test. The mechanism oil was changed every 1,000 hours starting at 500 hours. It should be noted that the treated screen was run outside in typical Wisconsin weather from July through January.

TABLE 11. - Abated Low-Head life test results

Test time, hours	Average sound pressure level, dBA	Loss factor
0	81.7	.10
1250	81.2	.12
2150	79.3	.12
3000	81.2	.11
4100	82.0	.09
5200	81.5	.09

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Deck Tests

In general, the non-metallic decks provide some benefit in noise reduction (2 to 7 dBA) but at a loss of efficiency (+1 to -10 percent), as compared to a steel wire cloth deck of the same open area. The additional penalty paid is that most steel decks have more open area than do the non-metallic decks, and therefore have a larger capacity at at the same efficiency. The performance, both noise and efficiency, of a particular deck depends, to a large extent, on the material being screened.

In the standard theory, when the efficiency is plotted against material flow, an inverted parabolic curve should be the result, with a point of maximum efficiency. At higher flow rates the deck should be less efficient due to the increased number of particles limiting the chances of a particular particle falling through a hole. At lower flow rates, the material would bounce too far, also lowering the number of chances. A straight line was assumed to represent the parabola in the narrow range of flow rates that could be run. The granite was run at near the maximum efficiency point, the dolomite was slightly above the maximum efficiency, and the coal was run below the maximum efficiency point. The data shows that the curve is slightly flatter than the theory predicts.

The theory also states that a maximum efficiency of about 95 percent should be obtainable, with an assumed ideal material. The granite efficiency was close to this, at about 92 percent average, but the dolomite was 12 percent lower at about 80 percent average. The dolomite and the granite were close in density, however the dolomite, being a sedimentary rock, tended towards rectangular cross-sections. The granite was of more rounded shape. A spherical particle would, of course, tend to pass through a hole much easier, since any orientation would fit. The rectangular particle would have to be turned just right to fit.

For some of the efficiency data points, lines with slopes other than assumed slope could be plotted. Whether the other slopes are true or not would depend upon the accuracy of the data. The duplication of a particular test was impossible because once the material flow was stopped, that same operating point could not be repeated. One method for checking the accuracy involved taking four efficiency samples at one flow rate. This yielded a ±2 percent difference from the average of the four efficiencies. This variation was probably caused by the small sample being taken when compared to the large volume in the hopper.

As a recommened continuation of this program, additional data points should be run at higher and lower flow rates, so that the entire efficiency curve can be developed. The present test stand is not capable of handling this. The conveyors are too small to handle higher flow rates, and feed problems, caused by material binding in the hopper gate and causing surging, prevents lower flow rates from being run. Equivalent higher flow rates could be obtained by testing a narrower screen or the addition of skirts to the present screen. With the narrower screen or the addition of skirts, the noise levels obtained would not be directly comparable. Lower flow rates could be accomplished by installation of a vibratory feeder on the hopper.

6.2 Low-Head Abatement

Three constrained layer damping treatments were comparison tested on the Low-Head screen. The reductions obtained ranged from 3.7 dBA for the 3-M treatment, to 4.7 dBA for the EAR treatment, to 4.9 dBA for the Antiphon treatment. A corrosion coating also tested yielded a .5 dBA reduction. The Antiphon damping treatment was tested with the mechanism isolators installed. The total reduction, measured without material, was 7 dBA. This includes 4.9 dBA from the damping and 2.1 dBA from the mechanism isolators. The configuration was life tested to 5,000 hours of actual operation in an outdoor environment with no loss of performance. Samples of the damping treatment were able to withstand an estimated 25,000 hours of accelerated testing in the severe conditions in a salt spray bath. The solution in the salt bath was mixed to duplicate coal plant wash water. The tests that were run at intervals were tensile strength of the visco-elastic material bond, and the loss factor. The loss in performance during these tests should not influence the noise abatement ability of the damping treatments. A sample mechanism isolator was also placed in the same bath, and showed no physical degradation that would affect its performance.

Sound tests on the Low-Head screen were run without material because the noise generated by the material would mask accurate readings of the effects of the screen treatments. In addition, the material test stand would have required extensive modification to run the horizontal Low-Head in place of the inclined Ripl-Flow. The actual sound level obtained while screening would depend upon three factors, 1) the hardness of the material, 2) the treatments of the deck and other screen surfaces that the material would strike, and 3) the screen itself. Sound levels with the best non-metallic decks using coal, the quietest material tested, are still over 90 dBA, and those tests were run with a screen and material system (no material) at a level of 77-79 dBA. The noise of the screen itself (no material) is more than 10 dB lower than the screen with material and changes to the screen would be readily masked by the material noise. The damping of the sidewalls would have some limited effect in reducing material noise, since the material does not usually strike the sidewalls.

As a next step, the recommendation is that the treatments developed during this program and a non-metallic deck be installed on several screens in actual plants, where the effects of the material on the noise and on the physical degradation can be monitored.

APPENDIX A: PROPOSED STANDARD METHOD FOR MEASURING SOUND FROM VIBRATING SCREENS

A.1 Purpose

The purpose of this standard is to provide a uniform procedure for measuring and reporting the sound pressure level and sound power level of vibrating screens.

A.2 Scope

This standard applies to all types and sizes of vibrating screens operating unloaded or loaded with soft coal or with aggregate. It specifies measurement procedures, operating conditions and reporting of results which are acceptable and expedient for use by non-specialists as well as by acoustical engineers.

The preferred method for obtaining sound pressure and sound power measurements is in a free-field environment. Recognizing that this may not be possible in all cases, a methodology is also defined in which the free-field levels are calculated from measurements in a semi-reverberant field. Consequently, the following parameters can be obtained with the procedures described in this standard.

Mean Sound Pressure Level at 1 meter for the condition of a free-field over a reflecting plane

- A-weighted overall
- Octave band
- 1/3 octave band

Sound Power Level

- A-weighted overall
- Octave Band
- 1/3 octave band

A.3 Instrumentation

A.3.1 Sound Level Meter

Shall comply with ANSI S1.4 - 1971, Type I and IEC 197. Effective microphone diameter shall be 25 millimeters (0.5 inch) or less.

A.3.2 Band Filter Networks

The octave and third-octave band filter networks shall comply with ANSI S1.11 - 1971, Class II for octave band filters and Class III for third-octave band filters. Band center frequencies shall be those specified by ANSI S1.6 - 1971 (given in Table A-5).

A.3.3 Ancillary Equipment

A.3.3.1 Interconnecting Cable - Shall not introduce noise interfering with the signal when flexed.

A.3.3.2 Microphone Signal Amplifier - Shall conform to applicable requirements of ANSI S1.4 - 1971.

A.3.3.3 Microphone Windscreen - Shall not affect the sound pressure level readings by more than ± 0.5 dB(A).

A.3.3.4 Anemometer - For measurement of ambient wind speed. Recommended accuracy is 10 percent at the highest wind speed allowed, 20 kilometers per hour (12 miles per hour).

A.3.3.5 Thermometer - For measurement of ambient temperature. Recommended accuracy is ± 1.0°C (± 1.8°F).

A.3.3.6 Barometer - For measurement of atmospheric pressure. Recommended accuracy is ± 1 kilopascals (±0.3 inches of mercury).

A.3.3.7 Rotational Speed - For measurement of mechanism speed. Recommended accuracy is ± 2 percent.

A.3.4 Sound Measuring System

As an alternative to making direct measurements with a sound level meter (Sections A.4.1 and A.4.2), a microphone or sound level meter may be used with a magnetic tape recorder and/or graphic level recorder or other indicating instruments.

A.3.4.1 Graphic Level Recorder - Shall record the level of the effective root-mean-square value of the sound pressure. The electrical frequency response of the level recorder shall be constant within 0.5 dB over the frequency range of interest.

A.3.4.2 Magnetic Tape Recorder - Shall be instrumentation grade and have a frequency response characteristic that is uniform (± 3 dB) over the range of at least 25 to 15,000 Hertz. This response shall be checked frequently and adjusted for optimum uniformity. Corrections for the remaining irregularities shall be applied to 1/3 octave band sound levels if they are used. Reproduced level stability shall be ±0.5 dB for successive recordings made of the same input level. Either a direct recording or frequency - modulation process may be used. Applied signal level shall be carefully adjusted to be within the dynamic range (signal-to-noise ratio) of the recorder.

A.3.5 Calibration

A.3.5.1 Acoustic - The sound level meter or sound measurement system shall be calibrated by applying an acoustic calibrator to the microphone producing a sinusoidal pressure at a frequency between 200 to 1250 Hertz. The calibrator shall have stable and well known response characteristics, be capable of a calibration precision of ± 0.5 dB, and preferably be of the reciprocity or pistonphone type. The calibration shall be performed at the beginning and end of each test period or test day, which ever is less. If these two calibrations differ by more than 1 dB, the sound pressure levels measured during that period shall be considered inaccurate and the test repeated. If the calibration continues to vary by more than 1 dB on repeated tests, the instruments shall be calibrated according to section A.5.6.2.

A.3.5.2 Annual - Every six months the frequency response of the sound level meter or sound measurement system (with or without microphone) shall be measured. Individual instruments shall also be calibrated annually using the manufacturer's recommended method of calibration. These calibrations shall be performed by a laboratory of recognized competence. A record of these calibrations shall be maintained.

A.4 Test Environmental

A.4.1 Free-Field Over Reflecting Plane (Preferred)

It is desireable to measure sound pressure levels in the free-field above a reflecting plane, uninfluenced by reflections from walls and nearby objects. The environment shall have a smooth reflecting plane extending continuously from the machine to beyond the farthest microphone. The average sound absorption coefficient of the plane shall be 0.1 or less (concrete or asphalt floors meet this requirement). Acoustically reflecting surfaces other than the machine and reflecting plane shall preferably be absent or at least no closer than $\lambda/2$ from the machine or within $\lambda/4$ from the microphone position, where λ is the wave length of sound at the center frequency of the lowest frequency band of interest (refer to Table A-1). Free-field conditions are determined by the qualification test of section A.4.3.

TABLE A-1. - Wavelengths of sound

Band center frequency, hertz	Half-wavelength ($\lambda/2$), meters (feet)	Quarter-wavelength ($\lambda/4$), meters (feet)
25	6.9 (22.6)	3.4 (11.3)
31.5	5.4 (17.8)	2.7 (8.9)
50	3.4 (11.3)	1.7 (5.6)
63	2.7 (8.9)	1.4 (4.5)
100	1.7 (5.6)	0.86 (2.8)
125	1.4 (4.5)	0.69 (2.2)
200	0.86 (2.8)	0.43 (1.4)
250	0.69 (2.2)	0.34 (1.1)

A.4.2 Semi-Reverberant Field (Acceptable)

Measurements may be made in rooms where the sound field is neither a free-field or a reverberant field. The room shall be large enough to permit measurement points on the prescribed surface without being closer than 1 meter (39.4 inches) to the ceiling, to any wall, or to any other reflecting surface.

A.4.3 Test Environment Qualification

To determine if the test environment has free-field or semi-reverberant conditions, the following test is performed. A small broad-band noise source shall be placed in the room at the position of the machine to be tested. Octave band sound pressure levels shall be measured at no less than 5 dispersed points at a radius of 4 meters from the acoustic center of the source. For these measurements, the microphone shall not be closer than 1 meter or $\lambda/4$, whichever is larger, to any wall or ceiling. Determine the band mean sound level. Additional octave band sound level measurements shall be made at a similar number of points which are on a radius of 2 meters from the source, on the same radial lines. Determine the band mean sound level. The difference of the two band mean sound levels shall determine the type of environment as in Table A-2.

TABLE A-2. - Measurement environment

Difference in band mean sound levels, dB	Field condition
Greater than or equal to 5	Free
Less than 5 but greater than 1	Semi-reverberant

A.4.4 Background Level

The background sound levels at the specified microphone locations shall be measured for all frequency bands of interest. If the increase in band sound level with the test machine operating is at least 10 dB greater than the background band sound level, then preferred conditions exist and no correction for background level is required. If the band sound level with the machine operating is between 3 to 9 dB greater than the background band level, the band sound level due to the test machine alone may be obtained by applying Table A-3.

TABLE A-3. - Background corrections

Difference in band sound levels, dB	Amount to be subtracted from machine band sound level, dB
3	3
4 through 5	2
6 through 9	1

If corrections of 3 dB are necessary, the corrected levels shall be reported with the figures enclosed in brackets: ( ). If the difference is less than 3 dB, the levels due to the machine alone cannot be measured accurately because the level of the machine is less than the background level. In such cases, the machine noise band levels shall be reported as "at least 3 dB below total measured sound".

A.4.5 Other Environmental Conditions

A.4.5.1 Ambient Temperature - Shall be within the range of -10 to 50°C (14 to 122°F).

A.4.5.2 Relative Humidity - Shall be with the range of 0 to 90 percent. Measurements shall not be made if condensation is present.

A.5 Procedure

A.5.1 Installation and Operation

A.5.1.1 Machine Mounting - Machine shall be installed and operated according to manufacturer's recommendations. Specific items of importance are: shaking frequency, mounting base, spring installation, and material throughput.

A.5.1.2 Operating Conditions - Tests shall be run at three operating conditions.

A.5.1.2.1 No Material - The screen shall be tested with no material feed.

A.5.1.2.2 Coal - The screen shall be tested with coal, 3 X 0 size.

A.5.1.2.3 Aggregate - The screen shall be tested with dolomite, 3 X 0 size.

A.5.2 Free-Field over Reflecting Plane

The following procedure is used if the test environment qualifies as a free-field using the test of section A.4.3.

A.5.2.1 Location of Microphone Positions - Microphones shall be located on the prescribed surface as shown in Figure A-1. The number of microphone locations and the size of the prescribed surface is determined by the machine size. The microphone positions shall be located on a rectilinear path spaced 1 meter from the major machine surfaces.

A.5.2.2 Measurement Technique - Sound pressure levels shall be measured for each frequency band of interest at all microphone locations for the following conditions:

1) Background level with machine off
2) Machine operating as defined in section A.5.1.

The "slow" meter characteristic shall be used.

The level is taken to be the average of the maximum and minimum levels during the period of observation.

If sound level at a microphone location exceeds adjacent levels by more than 5 dB, additional locations should be added midway between these locations. If tests of a number of machines are being made, background levels shall be measured at the beginning and end of each major test series. Sound levels shall be measured without observers in the immediate test area.

A.5.3 Semi-Reverberant Field

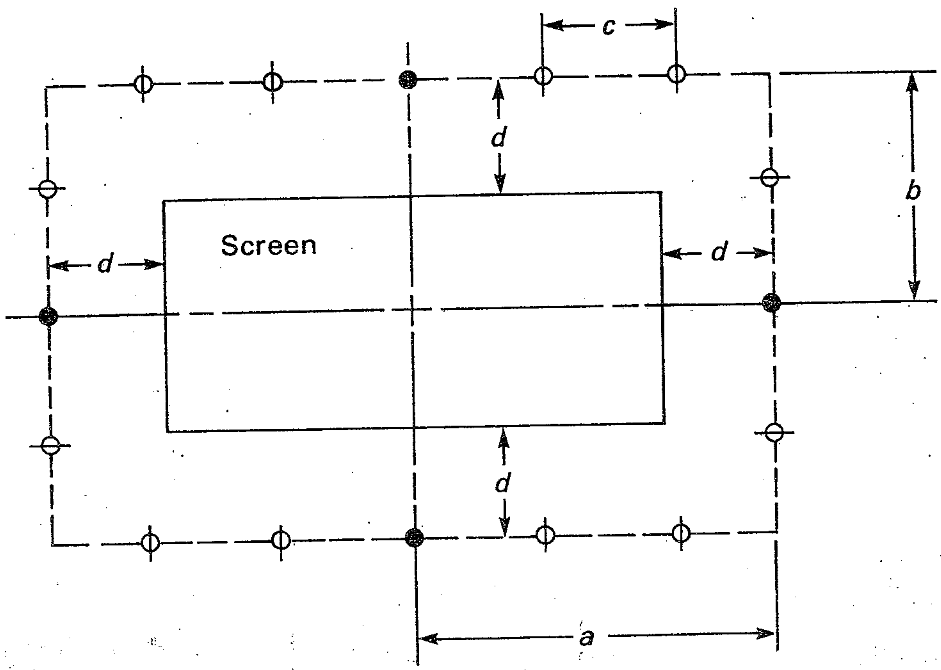
The following procedure is used if the test environment qualified as a semi-reverberant field using the test of section A.4.3. Using this procedure, the A-weighted mean sound pressure level for the condition of a free-field over a reflecting plane can be estimated.

A.5.3.1 Location of Microphone Positions - Follow the procedure of section A.5.2.1.

A.5.3.2 Reference Sound Source - A broadband sound source for which the output sound power level in the frequency bands of interest has been calibrated in a free-field, shall be used as the reference sound source. The source shall not have pure-tone components, i.e., the sound level in any 2 percent frequency band shall be below the corresponding octave band level by at least 10 dB. The sound power level in each frequency band shall not vary more than ± 0.5 dB between calibrations. Such sound sources are Bruel and Kjaer models 4204 and 4205.

The source shall be suitably mounted to prevent transmission, in the frequency range of interest, of vibration to the structure on which it rests. The directivity index in any 1/3 octave band shall not exceed 3 dB, relative to uniform hemispherical radiation.

A.5.3.3 Measurement Technique - Sound pressure levels shall be measured for each frequency band of interest, all all microphone locations for the following conditions:



Key microphone locations
O Ancillary microphone locations, as required
a = ½ screen length + 1.0 meter
b = ½ screen width + 1.0 meter
c = 2.0 meters maximum
d = 1.0 ±0.10 meters from screen body

Notes:

1. Microphone locations at mid-height along screen.
2. Ancillary microphone locations are added along rectilinear parimeter such that no microphone is more than 2.0 meters from another.

FIGURE A-1. — *Prescribed microphone locations*

1) Background level with machine off.
2) With reference sound source in operation at the location to be occupied by the machine to be tested.
3) Machine operating under one of the conditions of section A.5.1.2.

The "slow" meter characteristic shall be used. The level is taken to be the average of the maximum and minimum level during the period of observation. If sound level at a microphone location exceeds adjacent levels by more than 5 dB, additional locations shall be added midway between these locations. If tests of a number of machines are being made, background and reference source levels shall be measured at the beginning and end of each major test series. Sound levels shall be measured without observers in the immediate test area.

A.6 Calculation of Results

A.6.1 Free-Field over Reflecting Plane

A.6.1.1 Corrections - The sound levels measured at each microphone location shall be corrected for background level as described in section A.4.4.

A.6.1.2 A-Weighted Mean Sound Level ($\overline{L}_{pA}$) - This parameter can be determined from either of two methods.

A.6.1.2.1 From A-Weighted Sound Levels - The corrected A-weighted sound levels shall be averaged according to section A.9.7.

A.6.1.2.2 From Band Mean Sound Levels - Apply the A-weighting corrections as given in Table A-4 to the octave band or 1/3 octave band mean sound levels of section A.6.1.3. Sum the A-weighted band mean sound levels using the following equation:

$$\overline{L}_{pA} = 10 \log_{10}[\text{antilog } \overline{L}_{pbA}(1)/10 + \text{antilog } \overline{L}_{pbA}(2)/10 + \ldots$$
$$\ldots + \text{antilog } L_{pbA}(n)/10] \qquad \text{(A-1)}$$

where $\overline{L}_{pA}$ = A-weighted mean sound level, dB

$\overline{L}_{pbA}$ = A-weighted mean sound level of $n^{\underline{th}}$ band, dB

A.6.1.3 Band Mean Sound Level ($\overline{L}_{pb}$) - The corrected octave or 1/3 octave band sound levels shall be averaged according to section A.9.7.

A.6.1.4 A-Weighted Sound Power Level (L_{wA}) - The A-weighted sound power level is calculated with the equation:

$$L_{wA} = \overline{L}_{pA} + 10 \log_{10}(2 \pi r_s^2) \qquad \text{(A-2)}$$

where L_{wA} = A-weighted sound power level, dB

$\overline{L}_{pA}$ = A-weighted mean sound level, dB, as determined by section A.6.1.2

r_s = equivalent radius, meters, see section A.9.9

TABLE A-4. - Weighting corrections for band levels

Band center Frequency, hertz	Correction, dB Octave Band	Third-octave band
25.		-45
31.5	-40	-39
40		-35
50		-30
63	-26	-26
80		-23
100		-19
125	-16	-16
160		-13
200		-11
250	-9	-9
315		-7
400		-5
500	-3	-3
630		-2
800		-1
1000	0	0
1250		+1
1600		+1
2000	1	+1
2500		+1
3150		+1
4000	1	+1
5000		+1
6300		0
8000	-1	-1
10000		-3
12500		-4
16000	-7	-7
20000		-9

A.6.1.5 Band Sound Power Level (L_{wb}) - The octave or 1/3 octave band sound power level is calculated with the equation:

$$L_{wb} = \overline{L}_{pb} + 10 \log_{10}(2 \pi r_s^2) \qquad \text{(A-3)}$$

where L_{wb} = band sound power level, dB

$\overline{L}_{pb}$ = band mean sound level, dB determined by section A.6.1.3

r_s = equivalent radius, meters, see section 4.9.9

A.6.2 Semi-Reverberant Field

A.6.2.1 Corrections - The sound levels measured at each microphone location shall be corrected for background level as described in section A.4.4.

A.6.2.2 Band Mean Levels ($\overline{L}_{ps}$) - The corrected octave of 1/3 octave band levels shall be averaged according to section A.9.7.

A.6.2.3 Band Sound Power Levels (L_{wb}') - The octave of 1/3 octave band sound power levels can be obtained from the octave or 1/3 octave band mean sound levels by taking into account the influence of the test room. The band sound power levels are determined from the equation:

$$L_{wb}' = [L_{wr} - \overline{L}_{pr}] + L_{ps} \qquad \text{(A-4)}$$

where L_{wb}' = band power level of machine, dB, calculated from semi-reverberant data

L_{wr} = band power level of the reference source, dB

$\overline{L}_{pr}$ = band mean sound level of the reference source, dB

$\overline{L}_{ps}$ = band mean sound levels, dB, from section A.6.2.2.

A.6.2.4 Band Mean Sound Levels at the Distance of 1.0 meter for Conditions of a Free-Field over a Reflecting Plane ($\overline{L}_{pb}'$) - This quantity may be calculated with the equation:

$$\overline{L}_{bp}' = L_{wb}' - 10 \log_{10}(2\pi r_s^2) \qquad \text{(A-5)}$$

where L_{pb}' = band mean sound level at 1.0 meter

L_{wb}' = band sound power level, dB, from section A.6.2.3

r_s = equivalent radius, meter, see section A.9.9

A.6.2.5 A-Weighted Mean Sound Level at the Distance of 1.0 Meter for the Condition of a Free-Field over a Reflecting Plane - ($\overline{L}_{pA}'$) - Using the band mean sound levels from section A.6.2.4, apply the A-weighting corrections given in Table A-4 to obtain the A-weighted band mean sound levels, $\overline{L}_{pbA}'$. Sum these values using the equation:

$$\overline{L}_{pbA}' = 10 \log_{10}[\text{antilog } \overline{L}_{pbA}'(1)/10 + \text{antilog } \overline{L}_{pbA}'(2)/10 + \ldots\ldots + \text{antilog } \overline{L}_{pbA}'(n)/10] \qquad \text{(A-6)}$$

where $\overline{L}_{pA}$ = calculated A-weighted mean sound level, dB, at 1.0 meter

$\overline{L}_{pbA}'(n)$ = A-weighted mean sound level for n^{th} frequency band, dB

A.6.2.6 <u>A-Weighted Sound Power Level</u> (L_{wA}') - Using the band sound power levels of section A.6.2.3, apply the equation:

$$L_{wA}' = 10 \log_{10}[\text{antilog } L_{wb}'(1)/10 + \text{antilog } L_{wb}'(2)/10 + \ldots\ldots + \text{antilog } L_{wb}'(n)/10] \qquad \text{(A-7)}$$

where L_{wA}' = calculated A-weighted mean sound power level, dBA

$L_{wb}'(n)$ = band power level of machine for the $n^{\underline{th}}$ frequency band, dB

A.7 <u>Presentation of Results</u>

Results shall be presented in a report which contains the following information.

A.7.1 Acoustical Levels

Standard:

- A-weighted sound power level (L_{wA} or L_{wA}')
- A-weighted mean sound level at distance of 1.0 meter in free-field over reflecting plane ($\overline{L}_{pA}$ or $\overline{L}_{pA}'$)

Additional (to be specifically requested):

- octave or 1/3 octave band sound power level (L_{wb} or L_{wb}')
- octave or 1/3 octave band mean sound levels at distance of 1.0 meter for condition of free-field over reflecting plane ($\overline{L}_{pb}$ or $\overline{L}_{pb}'$)

A.7.2 Other Information

- operating conditions for which levels are reported and levels so identified
- reference to standard
- description of machine and installation
- description of test environment and location of tested machine
- make, model and serial number of instruments used

A.8 <u>References</u>

The following documents are referred to in this standard.

ANSI S1.8 - 1974 Preferred Reference Quantities for Acoustical Levels

ANSI S1.4 - 1971 Specification for Sound Level Meters

ANSI S1.11 - 1971 Specification for Octave, Half Octave, and Third-Octave Band Filter Sets

ANSI S1.9 - 1971 Preferred Frequencies and Band numbers for Acoustical Measurements

IEC 1979 Standard for Precision Sound Level Meters

A.9 Definitions and Terms

A.9.1 Sound Pressure Level

Twenty times the logarithm to the base ten of the ratio of the pressure of a sound to the reference sound pressure. The reference sound pressure is equal to 20 micropascals (per ANSI S.1.8-1974.) The sound pressures are expressed as effective (root-mean-square; rms) values. Unit: decibel (dB)

$$L_p = 20 \log_{10}(P/P_o) \qquad \text{(A-8)}$$

where L_p = sound pressure level, dB

P = effective (rms) sound pressure, pascals

P_o = effective (rms) reference sound pressure, pascals

= 20 micropascals

A.9.2 A-Weighted Sound Level

Weighted sound pressure level obtained by use of the metering characteristic and A-weighting specified in ANSI S1.4-1971 Unit: decibel (dB), denoted by dBA.

A.9.3 Octave Band Level

The sound pressure level for the sound contained within a band of frequencies having a range of one octave, as specified by ANSI S1.11-1971. The band center frequencies are those given in Table A-5 as specified by ANSI S1.6 - 1971.

A.9.4 Third-Octave Band Level

The sound pressure level for the sound contained within a band of frequencies having a range of one-third of an octave, as specified by ANSI S1.11-1971. The band center frequencies are those given in Table A-5 as specified by ANSI S1.6-1971.

A.9.5 Sound Power Level

Ten times the logarithm to the base ten of the ratio of the power of a sound to the reference sound power. The reference sound power is equal to 1 picowatt per ANSI S1.8-1974. The sound powers are expressed as average mean-square pressure values. Unit: decibel (dB)

$$L_W = 10 \log_{10}(W/W_o) \qquad \text{(A-9)}$$

where L_W = sound power level, dB

W = average sound power, watt

W_o = average reference sound power, watt

= 1 picowatt

TABLE A-5. - Preferred band frequencies for acoustical measurements

Octave band center frequency, hertz	Third-octave band center frequency, hertz
31.5	25 31.5 40
63	50 63 80
125	100 125 160
250	200 250 315
500	400 500 630
1000	800 1000 1250
2000	1600 2000 2500
4000	3150 4000 5000
8000	6300 8000 10000
16000	12500 16000 20000

A.9.6 A-Weighted Sound Power Level

The sound power level determined from the octave or third-octave band levels which have been weighted by adding the corrections given in Table A-4. Unit: decibel (dB)

A.9.7 Mean Sound Pressure Level of Mean Sound Level

This quantity is given by:

$$\overline{L}_p = 10 \log_{10} \frac{1}{n} [\text{antilog } L_p(1)/10 + \text{antilog } L_p(2)/10 + \ldots + \text{antilog } L_p(n)/10] \qquad \text{(A-10)}$$

where $\bar{L}_p$ = mean sound pressure level or mean sound level, dB

$L_p(n)$ = sound pressure level at the n^{th} measurement position, dB

n = number of measurement position

All L_p must be of the same weighting

If the maximum variation in the $L_p(n)$ is 5 dB or less, the mean sound pressure level may also be computed by the equation:

$$\bar{L}_p = \frac{1}{n} [L_p(1) + L_p(2) + \ldots + L_p(n)] + 1 \qquad \text{(A-11)}$$

where $\bar{L}_p$ = mean sound pressure level or mean sound level, dB

$L_p(n)$ = sound pressure level at the n^{th} measurement position, dB

n = number of measurement position

All L_p must be of the same weighting.

A.9.8 Prescribed Surface

An imaginary surface surrounding the machine on which sound measurments are made.

A.9.9 Equivalent Radius

Microphone locations on the prescribed surface should be assumed to have been made over a hemisphere of equivalent radius:

$$r_s = \frac{5}{6} (a^2 + b^2)^{1/2} \qquad \text{(A-12)}$$

where r_s = equivalent radius, meters

a and b are the dimensions in Figure A-1, meters

A.9.10 Background Level

The sound pressure level at the measurement positions of any sound not due to the machine being tested, including any test support equipment.

A.9.11 Machine

Any vibrating screen for which the sound is to be measured.

A.9.12 Frequency Range of Interest

The frequency range for which the octave band levels are within 40 dB of the highest octave band level.

John Seiler

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